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Investigations in Erosion Control and the Reclamation of Eroded Land at the Palouse Conservation Experiment Station, Pullman, Wash. 1931-42

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UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

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FOREWORD

Back of every great achievement is knowledge. Back of every successful human undertaking must be exact data for proper guidance of the enterprise.

Farmers of America have undertaken the gigantic task of producing more foods, fats, and fibres than America has ever produced before—vital crops needed for war. These crops—oils and fats, milk and cheese, meat and eggs, and many others—are as essential to winning the war as are tanks, planes, warships, and ammunition. Food is a first weapon of war. And our production goals will likely have to be even higher in order to feed the people of the world made hungry by war.

This puts a tremendous responsibility upon American farmers and a burden on their equipment. But American farmers know how to farm and how to get good crop yields.

It puts a strain on our farm lands, too. We do not have enough good land left under cultivation in America to do this job, *unless we use every means at our disposal to increase yields and to protect the soil while we are doing so.* And even then, we may have to bring some new land into cultivation—by irrigation, perhaps, or by drainage. Even some of the older erosion-impoverished lands may have to be put back into use through application of intensive measures for control of erosion.

Unless we take these precautions we must face such unpleasant alternatives as these: (1) We may fail to meet our war crop-production goals, and thereby prolong the conflict, or (2) much land may be laid waste by hazardous overcropping, and in this case the devastation, while less spectacular, would be no less real than that caused by bombs and shells.

These considerations put a premium on knowledge: That special kind of knowledge which will enable farmers to meet the vital war goals without so impoverishing their land that it cannot produce the even greater crops which the next succeeding year of war may demand.

This knowledge, supplementing the training and experience of American farmers as a group, points the way to a successful carrying out of the vital war crop-production enterprise upon which they have embarked and upon which America and a great deal of the world depend, today and tomorrow.

This publication contains much especially significant knowledge as it has been developed through study and research for the Palouse region of the Pacific Northwest. Briefly, it is a report of technical advances in conservation farming over a period of more than 10 years, showing not only methods used, but also the basic factors involved. They are set down clearly and they are authenticated by figures, plates, tables, and other data, concisely presented.

In effect, this report is a manual or handbook for technicians and for technicians only. Any soil and water conservation technician working in this region has in his copy of this report a handy pocket guide for determining degrees of slope for terrace channels on certain soils, the vertical fall between terrace crests, the expectancy of protection to be derived from various kinds of cover crops on different soils and slopes, the amount of water likely to be conserved from the average rains for crop use under various conditions of slope and soil treatment, and so on. Other reports are planned to provide the same useful data for technicians in other important farming regions.

They will contain a very large amount of quantitative data that will be particularly useful to agricultural engineers and crop specialists. In these hundreds of measurements, engineers have for the first time available data for computing the probable amount of water that will be delivered by various types of rains falling on the more common surface conditions over large areas of land in the Palouse wheat region of the Pacific Northwest. And by interpolation, the same data, considered coordinately with similar data from other regions' experiments can be used in making estimates of considerable reliability for many intervening land conditions.

These reports are not for general distribution, but in the hands of the technicians who work with the farmers they will be the means of putting into effect on the land more rapidly and more effectively than ever the essential measures to increase production for war.

H. H. BENNETT,
Chief, Soil Conservation Service.

Washington, D. C.

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DEPARTMENT OF AGRICULTURE
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Investigations in Erosion Control and Reclamation of Eroded Land at the Palouse Conservation Experiment Station, Pullman, Wash., 1931–42[1]

By GLENN M. HORNER, *project supervisor*, A. G. MCCALL, *senior soil conservationist*, and F. G. BELL, *chief, Erosion Control Practices Division, Research, Soil Conservation Service* [2]

The United States Department of Agriculture, Soil Conservation Service in cooperation with the Washington Agricultural Experiment Station

CONTENTS

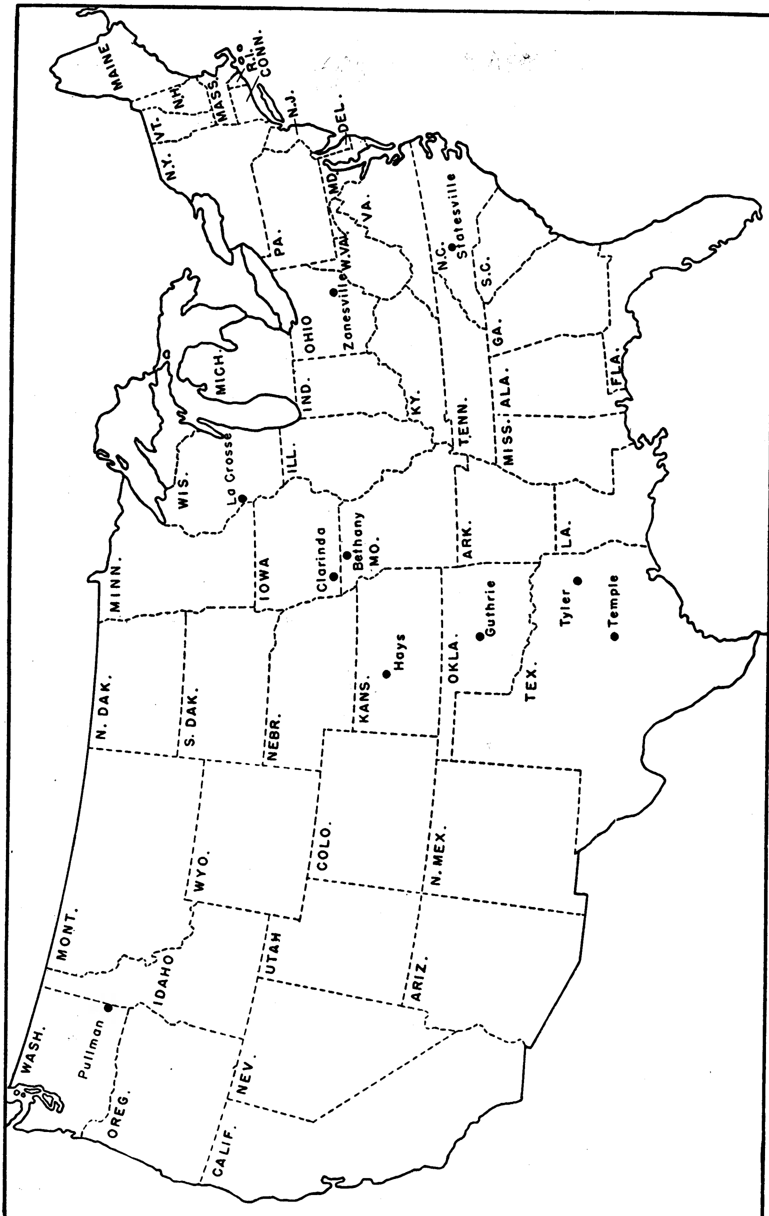
SUMMARY

The Palouse region, where most of the results of this station are applicable, has a steeply rolling, dunelike topography. The hills have south and southwest slopes which are longer and not as steep as the north and northeast slopes. Silt loam soils are dominant in the area, the most important of which is the Palouse series. The average annual precipitation at Pullman is 20.54 inches of which a large part occurs during the period from November to March. Rainfall intensities are relatively low in comparison with other sections of the country.

The most serious erosion has occurred on the hilltops, where the soils are shallow, and on the upper parts of south slopes. Climatic factors most closely related to the erosion problem are: (1) Prolonged winter rains falling on wet or saturated soil, (2) melting snow with or

[1] Submitted for publication May 1943.

[2] Former members of the station staff who contributed to the planning and development of the research program are W. A. Rockie, P. C. McGrew, C. E. Deardorff, and S. J. Mech. L. M. Naffiger and O. A. Leonard, who have been on the station staff continuously since the work was inaugurated, have contributed much to the accuracy of the work.



Map of the United States showing location of 10 soil conservation experiment stations.

without rain on frozen soil, and (3) intense summer rains which occur infrequently and are confined to small areas.

The amount of soil moisture present at the time of the storm is of greater importance than the amount or intensity of the precipitation. Rains of relatively low intensity falling on saturated soil cause heavy erosion losses while storms of larger amounts and greater intensities falling on dry soil result in no runoff. Other factors being constant, the intensity of the rainfall has a greater effect than the total amount.

The type of plant cover effects the amount of runoff and soil loss. The most effective cover tested was an established stand of perennial grasses which resulted in an average annual loss of 0.08 ton of soil per acre and 0.96 percent runoff. The common farming practice which resulted in highest soil and water losses was the seeding of winter wheat on summer fallow land. This practice caused an annual soil loss of 4.62 tons per acre and 5.52 percent runoff. A bare, untilled condition resulted in the loss of 22.08 tons of soil and 21.13 percent runoff. Winter wheat stubble standing over winter provide an effective erosion-control cover.

The cropping system designed for erosion control should furnish the maximum plant cover during each erosion season and provide sufficient soil nitrogen for the maintenance of a satisfactory soil-fertility level and development of a favorable soil structure. A 4-year rotation consisting of 2 years of sweetclover and 2 years of wheat, resulted in a significant decrease in erosion as compared to the conventional winter wheat-summer fallow system. The effectiveness of the sweetclover rotation became progressively greater after several cycles of the rotation had been completed. The effectiveness for erosion control of four 2-year rotations was found to be in the following order: (1) Hubam clover-winter wheat, (2) peas and spring wheat as a green manure-winter wheat (3) peas for seed-winter wheat, and (4) summer fallow-winter wheat. A cropping system is more effective for erosion control if spring wheat can be substituted for winter wheat; especially is this true in the area where crops are grown annually.

The erodibility of the soil is affected by the amount of soil organic matter present. Results show that land which has been cultivated for only a short period or has been treated with barnyard manure has lower soil and water losses than the same soil type with less organic matter.

Measurements show that at the end of the growing season the soil-moisture content for the upper 6 feet of summer-fallowed land was 20.9 percent as compared to 14.6 percent for winter wheat, 13.0 percent for bunchgrass, and 10.9 percent for alfalfa land. A relatively small amount of rain is required to saturate the summer-fallowed soil, a condition which contributes to greater runoff and erosion. At the start of the growing season, the soil moisture is highest on north slopes and lowest on the hilltops. On terraced south slopes the moisture content was highest under the terrace channel and lowest under the ridge and the down-slope side of the ridge.

Tillage practices should be carefully considered in formulating an erosion-control program. The utilization of crop residues to leave an adequate amount on the surface for vegetal cover and also the securing of a rough loose condition of the surface soil are effective practices for reducing runoff. Modified moldboard plows and differ-

ent types of subsurface tillage implements are being developed for this type of work.

Terracing studies were made to determine the adaptability of this practice in the Palouse region and to measure the effect of such terrace characteristics as length, vertical spacing, channel grade, and land slope.

Studies on the spacing of terraces indicate that a wider vertical interval can be used than in parts of the United States where rainfall intensities are greater. A terrace grade of 6 inches fall per 100 feet was found to be most satisfactory where the land slope was about 15 percent. A steeper grade resulted in soil movement along the channel, and with a flatter grade, snow obstructed the channel and caused frequent overtopping. Somewhat steeper grades are recommended for steep slopes than for gentle slopes, and for long terraces, the variable grade is recommended.

Terraces proved more satisfactory on slopes below 15 percent than on steeper slopes. On the flatter slopes a broad-base terrace can be constructed which allows farm machinery to cross more easily. Also, the plow furrow can be turned up the slope when desired and tillage equipment operated so as to help maintain the terrace.

Erosion measurements conducted on watershed areas show that the rate and amount of runoff is affected by watershed characteristics, climatic factors, and farming practices. The highest soil and water losses were obtained when the land was seeded to winter wheat following summer fallow.

INTRODUCTION

This publication is one of a series of reports designed to cover the first decade of experimental work at each of the 10 original soil erosion experiment stations established with funds appropriated by the Congress and carried in the appropriations for the United States Department of Agriculture.

Plans were developed for the establishment of experimental work on lands representative of large problem areas of eroding land in various parts of the country (*1*, *2*, *3*, *4*, *5*).[3] The locations of these stations are shown on the map of the United States (p. 2).

The research programs of the stations were designed to investigate the causes of erosion and to determine the most effective and practical methods of checking and controlling soil and water losses from the agricultural lands of the areas. This included experiments with various types of vegetative cover, soil treatments, cultural and cropping systems to determine their comparative effectiveness in preventing erosion, studies of the performance of terraces and check dams of different designs in removing runoff without injury to soil and crops, attempts to reclaim and revegetate eroded land, and the keeping of meteorological records. The findings of these experiments and the practical measures evolved to effect soil conservation have become vitally important as means of maintaining and increasing production since participation of this country in World War II.

In April 1935 the Soil Conservation Act was passed by which the National Government was definitely committed to the policy of soil and water conservation and provision was made for the establishment

[3] Italic numbers in parentheses refer to Literature Cited, p. 59.

of the Soil Conservation Service in the Department of Agriculture. The stations, at this time, became an integral part of the research activities of the Service.

The research program of the Soil and Water Conservation Experiment Station near Pullman, Wash., was established to obtain information on the problem of soil conservation in the Palouse wheat-growing region of the Pacific Northwest. The general objectives of this work are: (1) The determination of the factors affecting the rate and amount of soil erosion and runoff and (2) the development of practical measures for minimizing or controlling these losses, thereby protecting the fertility of soils for increased crop production.

The station was established in 1930 and is located 3 miles northwest of Pullman, Wash., within the wheat-producing area of eastern Washington. The research work in soil conservation is conducted in cooperation with the State agricultural experiment station.

This publication describes the investigational work of the station and summarizes the results obtained during the period from July 1, 1931, to June 30, 1942. Although records were taken during the first erosion season of 1931–32, no records are included prior to July 1, 1932, from experiments which required the establishment of a definite cropping system. Some studies have been terminated or new ones initiated from year to year as indicated in the discussion of the results.

THE PROBLEM AREA

The problem area to which the results of the station are most directly applicable is known as the Palouse Wheat Belt. This area consists of the wheat-producing section of eastern Washington and adjacent parts of Idaho and Oregon. It occupies a belt extending north and south between the foothills of the Rockies and Blue Mountains on the east and the Columbia River Plains of central Washington and north-central Oregon on the west (fig. 1).

Soils.—The soils of the area have marked variations associated with the prevailing climatic factors, especially precipitation. Each successive westerly belt of soils, having been developed under less rainfall, consists of soils lighter in color and with less definitely developed profiles than the soils to the east. They range from the light brown grassland types in the west to the very dark brown in the east. From west to east, the principal soil series are the Ritzville, Walla Walla, and Palouse.

The light brown Ritzville soils, chiefly silt loams, range in depth from a few inches on steep slopes of the major drainageways to 40 feet on some of the hilltops. Lime carbonate is usually present in distinct layers below a depth of about 30 inches. The area over which this soil prevails is a gently rolling plain. The dark-brown Walla Walla soils differ from the Ritzville principally in their greater depth to bedrock, higher content of humus, darker color, and greater depth to the carbonate layer. The Palouse soils are dark brown to black, high in content of silt and organic matter, and of a granular structure. They have a fairly thick silt loam surface horizon and a heavier clay to silty clay loam subsoil. The range in depth is from 10 to 100 feet over bedrock. Erosion has exposed the yellowish subsoil on many of the hilltops and ridges.

In detail, the Palouse varies from undulating to rolling with slopes

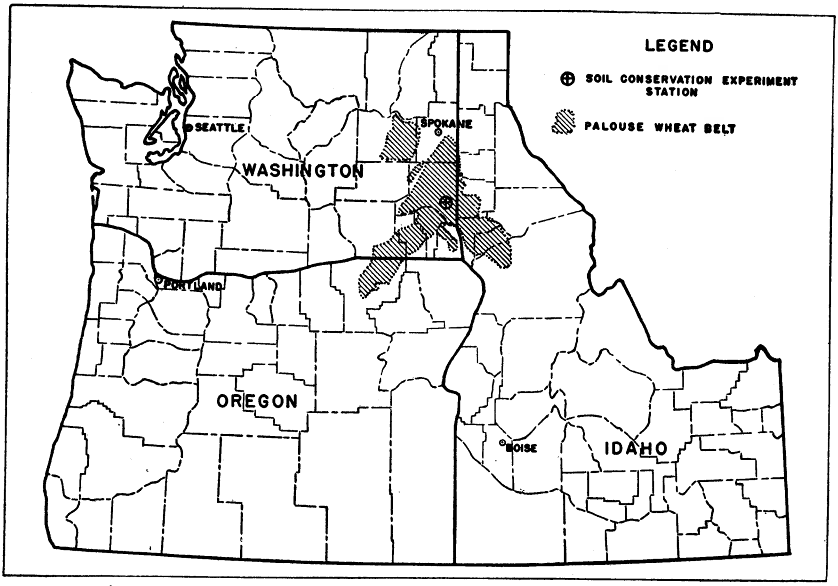


FIGURE 1.—Location of Palouse Wheat Belt problem area.

generally less than 15 percent in the western section to a typically dunelike hilly surface farther east. These dune-shaped hills, in general, have south and southwest slopes (windward) that are longer and not so steep as the north and northeast slopes (leeward). A considerable part of the cultivated land in the eastern part of the Palouse has slopes ranging from 10 to 40 percent. Some of the land has more than a 50-percent slope. A characteristic feature of this topography is the steep amphitheaterlike north and northeast slopes. Narrow valleys of alluvial land make up a well-defined drainage system. Many of the hills range from 100 to 200 feet above the bottoms of the valleys. Figure 2 is an oblique aerial view showing the topographic features of the Palouse region.

In the foothill section along the northwestern part of the Blue Mountains, the characteristic topographic features are the long, flat-topped ridges with uniform slopes separated by occasional deep canyons. The difference in elevation between the hilltops and valleys is sometimes 300 to 500 feet, and some slopes are a mile or more in length.

Climate.—The climate of the Palouse region varies from semiarid at the western edge to subhumid near the foothills on the east. From west to east the annual precipitation varies from about 12 to 35 inches. The entire area, however, has humid winters and dry summers. Figure 3 shows the average precipitation and mean temperatures by months as recorded by the Weather Bureau station at Pullman, Wash. Slightly over 60 percent of the annual precipitation of 20.54 inches occurs during the 5-month period from November to March, and only 5 percent during the 2 months of July and August. Since the bulk of the precipitation occurs during a period of low temperatures, the effect of the moisture is intensified by very low rates of evaporation. The surface soil has a high moisture content almost continuously from late fall to early spring.

FIGURE 2.—Aerial view of the Palouse region with Pullman, Wash., in the foreground.

Precipitation records for several locations in the problem area are shown graphically in figure 4 as 3-year moving averages. From these plotted data there are indications that the precipitation was at the high point of a cycle about 1900, and thereafter the trend was lower. There has been a marked variation in precipitation since the station was established in 1930. The high point reached in 1933 was followed by a rapid decline to a minimum in the 3-year period ending in 1936.

The total yearly precipitation at Pullman on the calendar-year basis has varied from 14.12 inches in 1935 to 30.87 inches in 1927. A study of the records at Pullman shows that a rain of between 1.01 and 1.50 inches in a 24-hour period occurs about once a year and a 24-hour rain of between 1.51 and 2.00 inches about once in 7 years. No record has been found of a rain greater than 2 inches in 1 day, although it is likely that by considering parts of 2 days, a single 24-hour rain in excess of this amount may have occurred.

The rainfall intensities in the Palouse region are comparatively low. The maximum 1-hour rainfall to be expected once in 5 years is 0.50 inch, and once in 50 years is 0.75 (*8*). Localized rains of a thundershower type greatly exceeding these intensities have occurred, but so far as known they were not measured by a recording gage. It is estimated that the most severe of this type of local storm results in a total precipitation of as much as 3 inches in a period of not longer

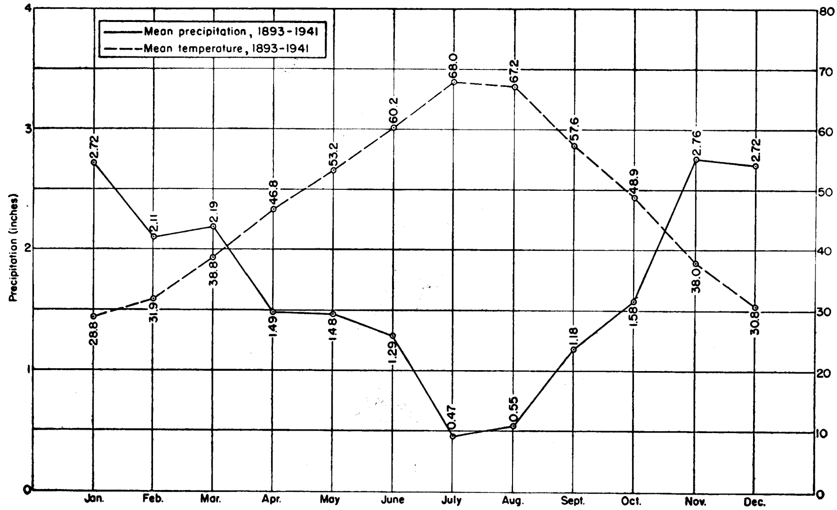


FIGURE 3.—Mean monthly precipitation and temperature as recorded by the Weather Bureau at Pullman, Wash.

than 1 to 2 hours. The frequency of these storms would be difficult to estimate, as some areas have had only one such storm since settlement 50 to 60 years ago, and other areas have not had a single storm of that kind during this period.

About one-sixth of the annual precipitation falls as snow. The amount of snow accumulation varies widely for different parts of the region depending on elevation and other factors. Individual snows or the accumulation of several snows may be melted rapidly by warm chinook winds and by rain. The soil may be frozen to a depth of about 1 foot, but in general, the depth is less and the periods of freezing weather are of relatively short duration. Rain or melting snow or both occurring when the soil is frozen, contribute to accelerated runoff and sheet erosion.

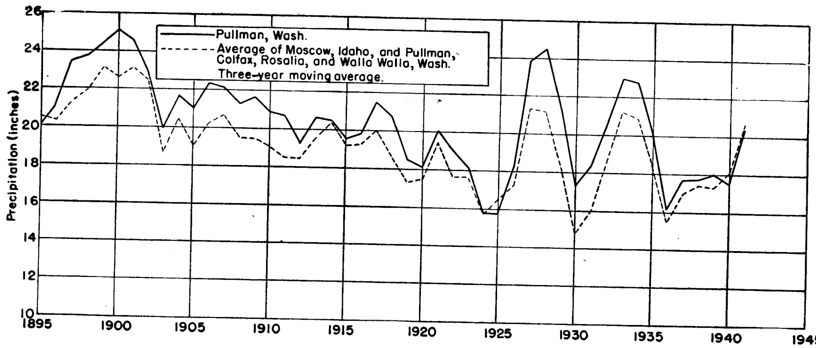


FIGURE 4.—Precipitation at different locations in the problem area for the period 1893–1941.

Erosion and Runoff History

Accelerated erosion has occurred in the Palouse region since the land was plowed from its original cover of bunchgrass. Most of the land has been cultivated 50 to 60 years. During this period, about 20 percent of the cultivated area has lost all or most of the topsoil through erosion while an additional 35 percent has been seriously damaged with about half of the topsoil lost. There is some wind erosion in the drier western edge of the area, but water erosion is dominant in the more humid localities. Sheet erosion is most common over a large part of the area. In the foothill section near the Blue Mountains, considerable damage by gullying has resulted on the longer slopes.

Erosion is undoubtedly more serious at present than during the period immediately following the breaking of the sod; nevertheless, the problem has been recognized for a number of years. Data published in 1922 by Sievers and Holtz (*7*) showed that after 39 years of farming certain of the soils had lost 34.5 percent of their organic matter and 22.1 percent of their nitrogen. The authors pointed out that erosion on steep slopes was severe and that the wheat-summer fallow system of agriculture did not make for permanency. Since the appearance of this publication, the additional depletion of soil organic matter and topsoil has greatly increased the erosion problem.

Several climatic and farming factors are closely related to the erosion problem on the cultivated lands of the Palouse. Over much of the area the summer-fallow system of producing grain is a common practice. The land is plowed in the spring, kept free of weeds during the summer, worked down to a seedbed of fine tilth in the fall, and planted to wheat. This system results in a large carry-over of soil moisture into the winter season. Although the rainfall intensities are relatively low as compared to those of other parts of the United States (*8*), the concentration of the precipitation during the part of the year when temperatures and evaporation are low may result in excessive accumulation of moisture in the soil profile. The infiltration of water under such conditions is greatly reduced. The lack of sufficient vegetal cover on much of the land during the rainy season is also an important factor contributing to the erosion problem. The most severe erosion damage occurs as a result of (1) rains of long duration although of relatively low intensities falling on wet or saturated soil, (2) melting snow with or without rain on frozen soil, (3) runoff flow across lower slopes and bottom-land resulting from the rapid melting of large snowdrifts located on steep north slopes, and (4) high-intensity summer rains which occur infrequently and are confined to small areas (*6*).

THE STATION

The experiment station farm of 202 acres is located 3 miles northwest of Pullman in Whitman County, Wash., in one of the more humid eastern sections of the Palouse region. The conditions at the station are typical of the surrounding area insofar as factors of climate, topography, soils, and erosion are concerned. The land has been the property of the State College of Washington since the establishment of the station in 1930. Before that date it was privately owned and cropped almost exclusively under the wheat-summer fallow system for a period of 40 to 50 years.

FIGURE 5.—Aerial view of the Soil and Water Conservation Experiment Station, Pullman, Wash., 1933.

DESCRIPTION

Topography.—The elevation of the station ranges from 2,471 to 2,656 feet above sea level. There are four hills on the farm where the slope is as great as 50 percent on the steepest part. These steep slopes have a leeward (northeasterly) exposure and give rise to an amphitheaterlike topography which permits the formation of large snowdrifts just below the crest of the hill. These slopes are typical of a large area around the station but are shorter and steeper than the slopes found on the western edge of the Palouse and in the sections adjacent to the foothills of the Blue Mountains. An aerial view of the farm is shown in figure 5.

Soils.—The soils of the experiment station farm consist of the Palouse silt loam, Palouse silty clay loam, shallow phase, and Chamber silt loam. The soil type is an important factor in erosion because the characteristics of each type may affect the rate of infiltration, pore space, water-holding capacity, and resistance to washing. Figure 6 shows the location, exposure, and extent of the different soil types together with topographic features and the erosion classification.

The Palouse silt loam is the most extensive type, covering 76 percent of the farm. The surface layer consists of 9 to 26 inches of dark-brown to black friable silt loam high in organic matter. Under normal conditions, the soil structure is granular and permits a rapid absorption of moisture. This layer is underlain to a depth of 24 to 44 inches by dark-brown silt loam somewhat finer in texture, slightly more compact, and lighter in color. A grayish, light silt loam to sandy layer varying from a very thin layer to one several inches thick is usually encountered at the lower portion of the surface layer. It is in this layer that

considerable lateral movement of water takes place, producing seep spots and soil slips.

The third distinct layer is a dark-brown silty clay to clay, very tough and impervious. The structure is columnarlike and the cleavage planes are stained with dark, organic colloidal material. This layer varies from 4 to 14 inches in thickness, and is underlain by a yellowish-brown heavy clay layer that is usually many feet thick and extends to the underlying basalt.

The upper layers of the profile of this type vary on different slopes and exposures. The surface layer is thicker on the more gentle slopes. This layer reaches its greatest thickness on north slopes at points covered by snowdrifts during the winter. This greater depth under the drift is largely a result of the building up of the soil which has been filtered out of the runoff water by the snow, and the washing away of the soil below the drifts.

The Palouse silty clay loam, shallow phase, is confined for the most part to hilltops, ridges, and upper portions of slopes. It occupies 16 percent of the area of the farm and represents the most severely eroded condition. This soil is scattered throughout the area as small irregular patches, occupying the higher elevations. It consists of a few inches of yellowish-brown silty clay, which is underlain by a yellowish-brown and in some places a slightly reddish-brown heavy clay. The organic matter content is very low. Under the extreme erosion conditions, the silty surface layer has been completely removed and during cultivation the remnant of the heavy prisimatic clay is mixed in with the upper few inches of the heavy clay sub-stratum.

Alluvial soil in small areas along the flatter drainage channels is classed as Chamber silt loam. It is found on 8 percent of the station farm. The surface layer consists of 15 to 18 inches of compact black silt loam high in organic matter. This soil is generally very wet during the winter and spring months with the ground-water table at or near the surface. In poorly drained places it is a dark-gray, heavy silt loam. This is underlain by a waxy, drab, very compact clay, sometimes mottled with gray.

Relative productivity of different parts of a field is closely related to the soil type. The Palouse silt loam is the most productive of the types found on the farm and represents the main body of soils suitable for the growing of cultivated crops. The Palouse silty clay loam is relatively unproductive, especially on the severely eroded hilltops, where the yields of grain, peas, or other annual cultivated crops are generally so low that the land is farmed at a loss. For this reason as well as for erosion control, this type of land is best adapted to the growing of perennial plants, such as grasses and alfalfa. The crop yields from much of the Chamber silt loam are low because of the poorly drained condition of the soil.

An erosion survey of the station farm shows that slight sheet erosion has occurred on 24 percent of the land, moderate sheet erosion on 43 percent, moderately severe sheet erosion on 17 percent, and severe sheet erosion on 16 percent. A large proportion of the severe erosion has occurred on areas classed as Palouse silty clay loam soil. The Chamber silt loam and the more gently sloping Palouse silt loam soils have been damaged only slightly by eroison.

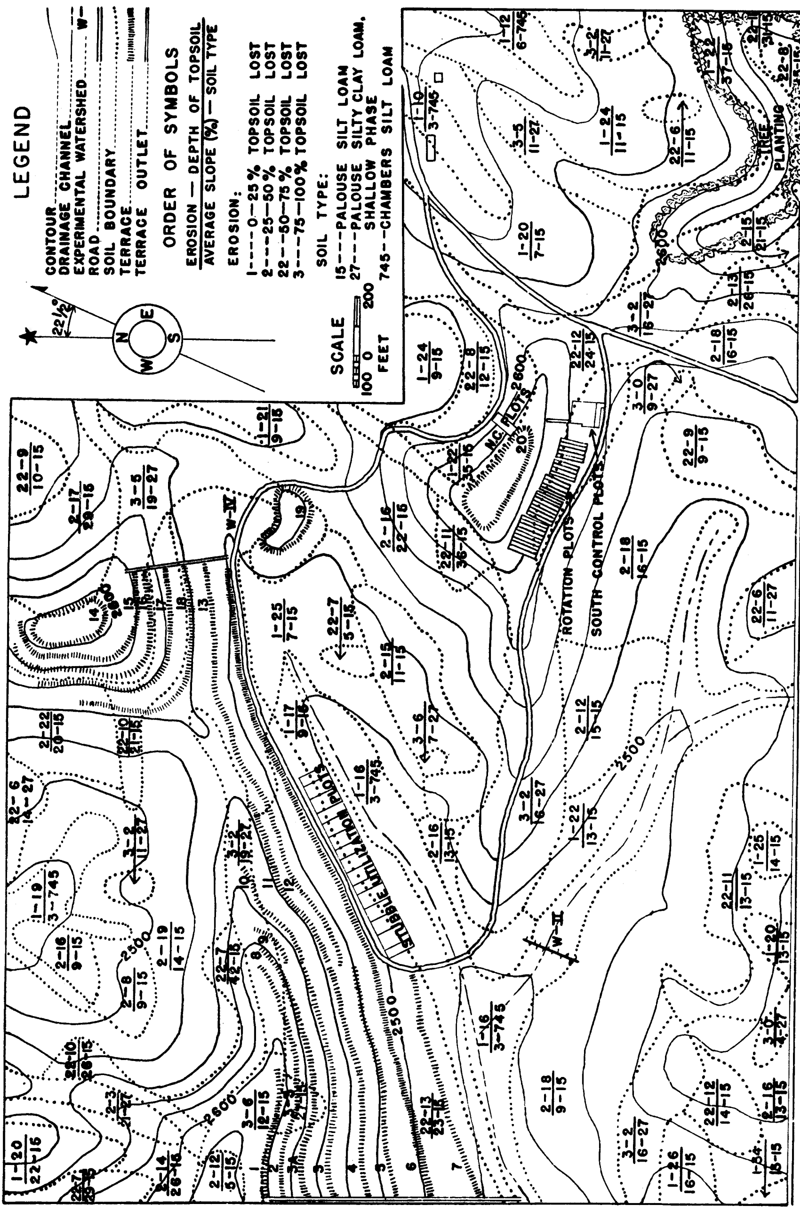


FIGURE 6.—Map of the Soil and Water Conservation Experiment Station, Pullman, Wash.

PURPOSE AND PLAN OF EXPERIMENTS

The primary objectives of the experiments at the station are to determine the variables affecting the rate and amount of soil erosion and runoff, to study the fundamental processes relating to losses of soil and water, and to develop practical measures for retarding or controlling these losses. Specifically, the problem consists of the determination of the effect of such factors as soil characteristics, vegetal cover, land use, topography, and climate on the rate and amount of soil erosion and the development and testing of such control measures as cropping and tillage practices, terracing, and gully and channel protection. The projects under study are:

1. The effect of different plant covers on soil and water losses.
2. The relation of crop rotations to soil and water losses.
3. Studies of soil erodibility as affected by soil organic matter and depth of surface soil.
4. The development of methods of managing uncultivated plant covers.
5. The development of tillage practices to conserve soil and water
6. Runoff and erosion from terraced and unterraced agricultural watersheds of different types and sizes.
7. The influence of the length and degree of slope on soil erosion and the development of conservation practices based upon the modifications of slope characteristics by terracing and similar practices.

Measurement of Erosion Losses

Water and soil losses as affected by different factors are determined under measurable conditions. The areas under study include small plots, terraced areas, and different sized watersheds.

South control series.—These plots are located on a 30-percent south slope of Palouse silt loam soil. The set-up consists of 13 plots of $\frac{1}{100}$ acre each, 1 plot of $\frac{1}{200}$ acre (plot 1) and 1 plot of $\frac{1}{50}$ acre (plot 2) with all plots 6 feet wide. The standard length of the plots is 72.6 feet except for plot 1 which is half length and plot 2 which is double length, to provide for a comparison of the effect of slope length upon runoff and soil loss. Each plot is enclosed with sheet-metal borders to prevent leakage or intake of water, and is provided with a metal tank at the lower end to catch the runoff and eroded material (fig. 7). The quantities of water and eroded material lost during each runoff period are measured and the results correlated with the different cropping and cultural practices followed on the various plots.

Plots 1, 2, and 3 have the same treatment, namely, winter wheat alternating with summer fallow. The wheat stubble of the previous year's crop is spaded under in April and the soil kept free of weeds by harrowing and rod weeding until winter wheat is planted in October. The soil is bare in alternate summers and has only a scant covering of winter wheat the fall and winter following. The soil is protected by a cover of wheat stubble from July to April of the second year.

A 4-year rotation is followed on plot 4. Sweetclover is seeded in the early spring without a nurse crop and in June of the following year the top growth is turned under as a green-manure crop. After the sweetclover is plowed under, the soil is fallowed the remainder

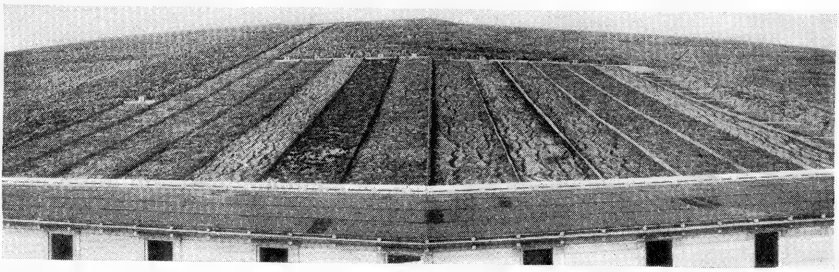


FIGURE 7.—South control plots, 30-percent south slope. Plots are numbered from left to right. March 31, 1932.

of the summer and seeded to winter wheat in October. Spring wheat is grown the last year of the rotation. Stubble is allowed to stand over the winter following each of the two wheat crops.

Plot 5 is cropped to winter wheat followed by summer fallow. The soil is tilled 16 inches deep with a chisel spade after the removal of the crop and immediately preceding tillage for fallow.

Plot 6 is planted to a mixture of perennial grasses, smooth brome (*Bromus inermis*) slender wheatgrass (*Agropyron pauciflorum*), and tall oatgrass (*Arrhenatherum elatius*). The crop is cut for hay each year.

Plot 7 is planted to spring wheat each year, on spring-tilled land, and fertilized at the rate of 200 pounds of ammonium sulfate per acre at the time of planting.

Plot 8 is cropped to winter wheat, which is alternated every other year with summer fallow. This is a common cropping practice over a large part of the wheat-growing section of the region.

The 4-year rotation followed on plots 9, 10, 11, and 12 consist of peas for grain and as a nurse crop for sweetclover, sweetclover turned under in June as a green manure, fallowed and seeded to wheat in October, and spring wheat the fourth year. Each crop of the rotation is represented every year on one of the plots.

Plot 13 is neither cropped nor cultivated, the weeds being kept down by scraping with a hoe or by pulling.

Plot 14 is a study of erosion on subsoil. The surface soil was removed and the subsoil is cropped according to the winter wheat summer-fallow system.

Plot 15, from which the surface soil was removed and replaced with subsoil from another area, was established as a supplement to plot 14. The excessive amounts of drifting snow retained on the latter makes it difficult to secure comparable results for those years when much of the precipitation is in the form of snow.

Crop-rotation plots.—The series of plots designated as the crop-rotation plots are located on a 30-percent south slope of Palouse silt loam soil. This experiment consists of 29 plots 13 feet wide and 91 feet long. Runoff soil losses, and crop yields are measured from an area 10 feet wide and 87.1 feet long. The 3-foot strips between the areas takes care of the border effect of the different treatments. The catchment system for this series of plots consists of a primary tank and a smaller secondary tank. The primary tank is of sufficient size to store the material from most of the runoffs, but when it is

filled to capacity, the excess runoff water is passed through a multiple-slot divisor and an aliquot is retained in the secondary tank (fig. 8).

The cropping and tillage practices on this set of plots are carried out in accordance with the rotations listed in table 1. During the periods that tillage and seeding operations are being performed, the sheet-metal borders are removed from around the plots to permit the use of small standard-type equipment on both the plot and border area. The type of tillage obtained with this procedure more nearly duplicates regular field operations than in the case when hand tools are used. Straw is returned to the wheat and pea plots after threshing and no stubble is burned.

TABLE 1.—*Cropping system on crop-rotation plots*

Rotation No.	Rotation Duration (years)	Plot Nos.	Description of rotations
1	2	9, 22	Winter wheat the first year, stubble left over winter, fallowed the second summer with wheat seeded in fall.
2	2	3, 16	Spring wheat the first year, stubble left over winter, fallowed the second summer with wheat seeded the following spring.
3	2	10, 29	Winter wheat the first year, stubble left over winter, peas (for seed) the second year with wheat seeded in the fall.
4	2	12, 25	Spring wheat the first year, stubble left over winter, peas (for seed) the second year, fall plowed with wheat seeded the following spring.
5	2	14, 21	Winter wheat the first year, stubble left over winter, mixture of peas and spring wheat for green manure the second year with wheat seeded in the fall.
6	2	4, 18	Spring wheat the first year, stubble left over winter, mixture of peas and spring wheat for green manure the second year with wheat seeded the following spring.
7	2	7, 28	Winter wheat the first year, stubble left over winter, Hubam clover for green manure the second year with wheat seeded in the fall.
8	2	6, 19	Spring wheat the first year, stubble left over winter, Hubam clover for green manure the second year with wheat seeded the following spring.
9	5	2, 8, 15, 23, 27	Mixture of sweetclover and grass seeded the first year and plowed under as green manure the second year, winter wheat the third year, stubble left over winter, peas (for seed) the fourth year, fall plowed wheat seeded the following spring.
10	8	1, 5, 11, 13, 17, 20, 24, 26.	Mixture of alfalfa and grass for 4 years, spring wheat the fifth year, winter wheat the sixth year, stubble left over winter, peas (for seed) the seventh year, fall plowed with wheat seeded the following spring.

North control plots.—Six 1/100-acre plots were established in 1933 on a northeasterly 48-percent slope for the purpose of determining under different cropping practices the amount of erosion caused by the melting of deep snowdrifts formed on north slopes. The type of installation consisted of sheet-metal dividers between plots and a concrete retaining wall at the lower end of the slope.

A relatively large lateral movement of water occurs through the subsurface layer of soil at this location. The retaining wall at the lower end of the plots caused this water to rise to the surface as seepage, which then passed over the weir and was collected in the runoff catchment tanks. Thus, the surface runoff from the plots was usually mixed with seepage water, and although several attempts were made no satisfactory method was found to separate the two types of water and determine the amount of each present. This experiment was discontinued in 1940 because of this discrepancy in the results.

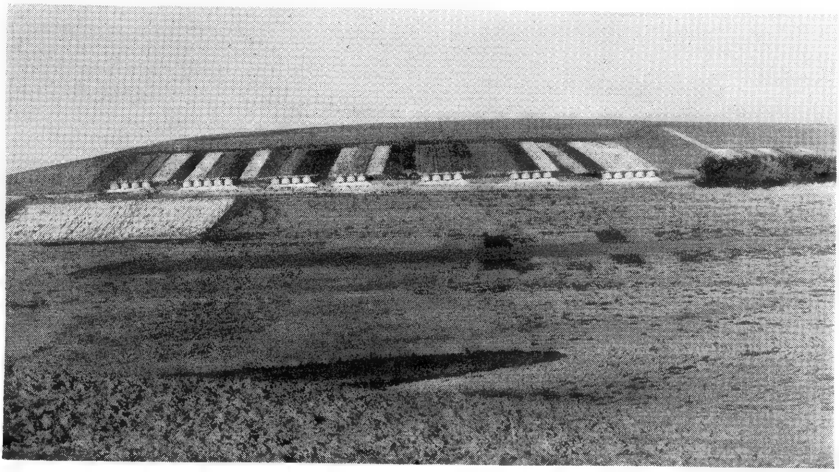


FIGURE 8.—Crop-rotation plots, 30-percent south slope.

College farm plots.—A group of six control plots is located on the college farm on a 22-percent south slope of the Palouse silt loam soil (fig. 9). Three of the plots are on land that had never been cultivated prior to 1934 when the experiment was inaugurated. Plots 1 and 2 are cropped according to the winter wheat-summer fallow system (when one plot is in wheat the other is fallowed) and plot 3 had the original stand of native bunchgrass. A second series of three plots is located adjacent to the virgin area on land that had been devoted to the growing of wheat for a period of more than 50 years. The cropping treatment of the two groups of plots is the same, plot 3 of the latter group

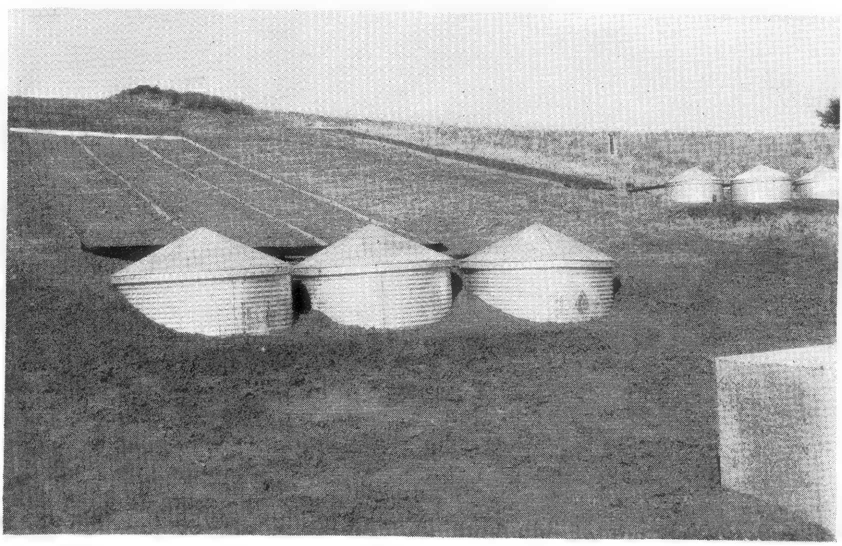


FIGURE 9.—College farm plots, 22-percent south slope. Cultivated area is to the left and virgin area to the right.

having been seeded to a grass mixture in 1936. The principal objective of this experiment was to determine the effect of the content of soil organic matter on erodibility. A marked reduction in soil organic matter and depth of topsoil occurred during the long period of cultivation when compared with the virgin or uncultivated soil. The general procedure for handling these plots is the same as that described for the first series of control plots.

Idaho plots.—Supplementing the work at the Pullman Experiment Station measurements of soil and water losses have been made on six of the rotation plots located at the Idaho Agricultural Experiment Station at Moscow. Three of these plots received applications of organic matter while the other three (plots 3–B, 8–D, and 11–E) received no treatment. All six plots are cropped to winter wheat each year. On each of the selected plots, an area 6 feet wide and 90.7 feet long is equipped with sheet-metal borders and a metal catchment trough and tank for the collection of runoff material. All equipment except the tanks is removed from the plots during the harvesting and seeding periods. The farming operations are conducted with field-scale machinery.

Terraced areas.—Determinations of soil and water losses were made on several terraced areas during the 7-year period from July 1921 through June 1938. These terraces were constructed on 12- to 30-percent slopes of the Palouse silt loam soil. Table 2 gives a description of these terraces, showing drainage area, land slope, vertical spacing, length, and grade. Most of the terraces are on south slopes although some continue around the hill on a west slope (fig.6).

TABLE 2.—*Description of the terraces and unterraced areas for which measurements of runoff and soil loss are given in the tables indicated*

Terrace or area No. and tables in which rainfall, runoff, and soil loss are recorded	Drainage area	Land slope	Vertical interval	Length	Grade
	Acres	*Percent*	*Feet*	*Feet*	*Inches per 100 feet*
Tables 16 and 30:					
3 [1]	2.26	27.6	35.0	780	12
3 [2]	1.22	28.6	20.0	780	12
3A	1.04	27.1	15.0	780	12
4	1.85	24.7	25.0	780	12
5	1.26	20.8	15.0	780	12
Tables 18 and 31:					
2	.56	26.0	15.0	400	12
5	1.26	20.8	15.0	780	12
6	4.68	16.8	15.2	2,274	12
Tables 19 and 32:					
13	1.52	14.2	13.8	780	0
18	1.18	20.2	14.0	780	6
17	.92	25.2	14.5	780	12
16	.82	26.6	13.5	780	18
15	.89	23.4	17.0	685	24
Tables 20 and 33:					
7	2.09	13.4	15.0	780	12
5	1.26	20.8	15.0	780	12
17	.92	25.2	14.5	780	12
3A	1.04	27.1	15.0	780	12
Tables 21 and 22:					
W-IV	2.33				
W-V	14.4				
W-VI	15.2				
W-II	68.2				
W-VIII	762				
W-VII	16,700				

[1] Before construction of terrace 3A.
[2] After construction of terrace 3A, October 1932.

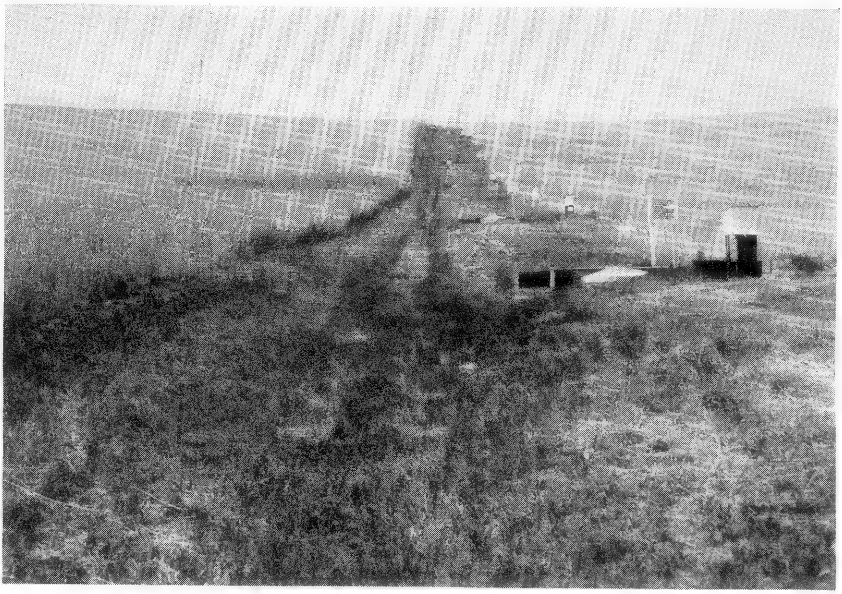


FIGURE 10.—Runoff measuring equipment at the outlet ends of terraces.

All of the terraced land was cropped during the period of the experiment to winter wheat-summer fallow. The wheat was threshed with a combine harvester and the stubble left to stand over winter. An orchard-type disk was used for the initial spring tillage operations to work the stubble into the surface soil in preparation for summer fallow. Subsequent cultivation was done with a revolving rod-weeder until wheat was seeded in the fall. With this system, good erosion control was furnished every other rainy season by the standing stubble, but severe erosion conditions existed during the season following the winter wheat seeding on fallowed land.

Erosion losses at the ends of the terraces were determined by means of water-level recorders, Parshall flumes, and Ramser silt samplers installed at the outlet ends of the terrace channels (fig. 10).

Watershed areas.—The purpose of this study is to compare runoff and erosion from field areas of different size with that from small plots and terraces and to secure information needed in the design of farm stock ponds, channel and flood control, and other conservation structures. Six areas of typical agricultural land ranging in size from 2.33 to slightly more than 16,000 acres of the Palouse region, cropped in accordance with the common practices of the area, were selected. They are designated by the numbers W–II, W–IV, W–V, W–VI, W–VII, and W–VIII. Results are recorded in table 21.

Parshall flumes with water-level recorders were used until 1939 for measuring runoff from all except W–VII. On this area a water-level recorder was used and a rating curve established. The Parshall flumes on W–II, W–V, W–VI, and W–VIII were replaced with triangular broad-crested weirs in the summer of 1939.

Other Investigations

In addition to the projects where soil and water losses were measured, investigations have been made of other factors affecting the problem in this region. Included in these studies is the development of tillage practices designed to utilize crop residues and increase surface storage in order to reduce erosion losses. Different implements in common use or recently introduced are tested under field conditions. Modifications of these implements are being developed for the purpose of improving their performance. Information is recorded as to the efficiency of various tillage practices for erosion control and the effect on crop yields, physical characteristics of the soil, and other factors.

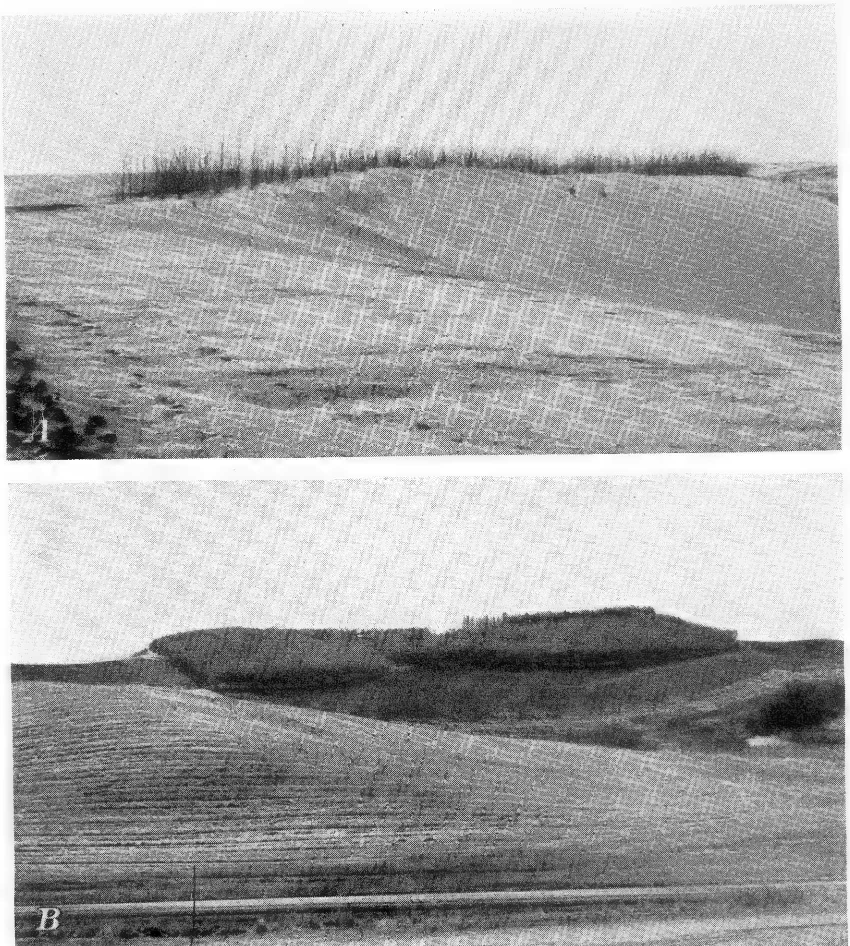


FIGURE 11.—Tree planting at soil conservation experiment station. *A*, Snowdrift held by hilltop planting, February 19, 1937; *B*, general view of hilltop and adjacent north-slope planting, June 1942.

Soil-moisture measurements were made in order to determine the effect of the type of crop, topographical features, soil type, and different soil-management practices on the amount and distribution of moisture in the soil profile.

Trees were planted (fig. 11) on a severely eroded hilltop and the adjacent steep north slope in order that a study might be made of the utilization of such land for tree production, the effect of trees on the formation of snowdrifts on north slopes, and the effectiveness of trees in controlling erosion and conserving moisture. The hilltop was planted in 1932 with two rows of Russian-olive (*Elaeagnus angustifolia*) on the windward side, then two rows each of *Caragana* (*Arborescens*) and Asiatic elm (*Ulmus pumila*), and five rows of black locust (*Robinia pseudoacacia*). On the leeward side and just below the crest of the ridge are two rows of Douglas fir (*Pseudotsuga taxifolia*) and one row of Norway spruce (*Picea excelsa*). In 1937 an area of 6 acres on the adjacent steep north slope was planted to trees, which consisted largely of black locust with small numbers of nine other species distributed through the planting. Soil-moisture determinations are made periodically and observations of tree growth and snow accumulation are recorded.

Studies have been made of methods of water disposal as related to gully and terrace-outlet control based on mechanical or vegetative practices, and stabilization of field waterways.

Studies also have been made to determine what crop rotations and tillage practices are effective on land that is adapted to the growth of cultivated crops, such as wheat and peas. Experience has indicated that excessively steep or severely eroded land requires other control practices, such as the use of uncultivated plant covers. Better methods of managing these crops were evolved from study and experiments and have been put into practical application.

Contributing Records

Climatic data.—Detailed precipitation records have been taken at a number of locations on the farm and the experimental watersheds. Both Fergusson-type recording raingages and Weather Bureau standard gages are installed at each location. Additional climatological data included maximum and minimum temperatures, relative humidity, and wind movement.

RESULTS OF EXPERIMENTS

The data dealing with runoff and erosion is presented for the most part on the erosion-year rather than the calendar-year basis. In this problem area with relatively high winter and low summer precipitation, the erosion generally commences in October or November and continues until March or April. These dates may be earlier or later some years, but practically all of the erosion occurs between the time fall-tillage operations are completed and the spring work is begun. Therefore, no significant changes are likely to occur in the condition of the plant cover during the erosion season. An analysis of the data on a yearly basis beginning July 1 and ending June 30 is used in order to eliminate as much as possible the variations in tillage and plant cover.

Rainfall Characteristics and Erosion

The amount and intensity of precipitation has an important effect on erosion. Rain falling on soil will cause runoff when the moisture-

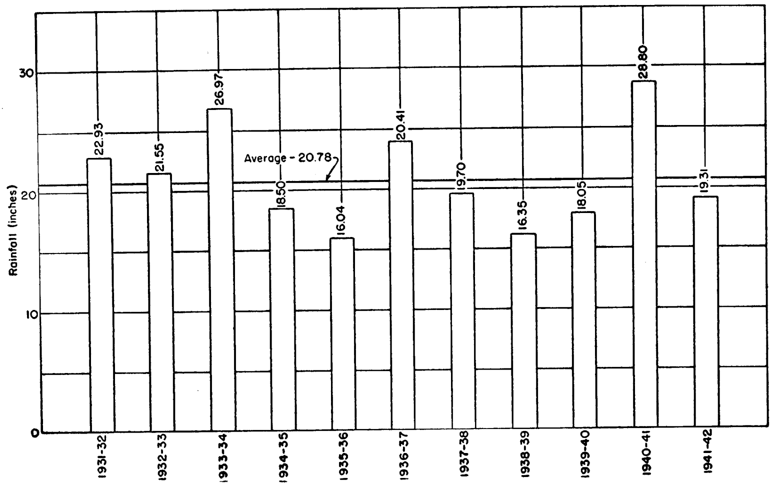


Figure 12.—Annual and average precipitation for the 11-year period July 1, 1931, to June 30, 1942, from field 3 gage at the Soil Conservation Experiment Station, Pullman, Wash.

holding capacity of the soil is exceeded or when the rainfall rate exceeds the rate at which water can infiltrate into the soil. The characteristics of the soil determine when this point is reached.

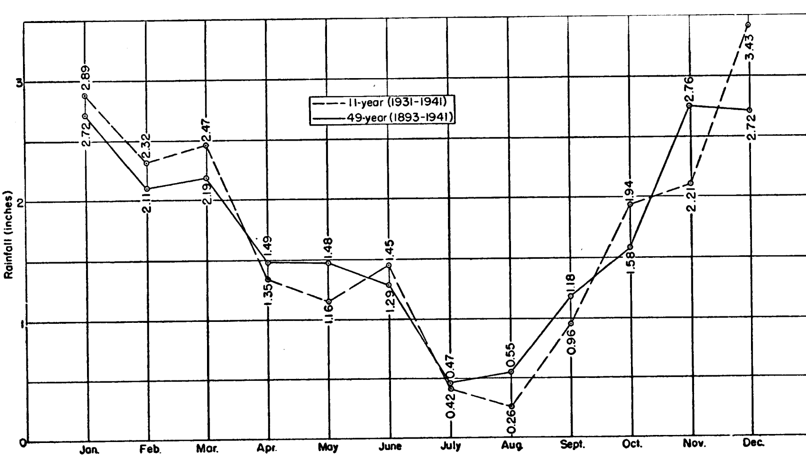


Figure 13.—Average precipitation distribution by months for the 11-year period 1931–41 and the 49-year period 1893–1941.

A summary of the precipitation recorded at the station for the 11-year period, July 1, 1931, to June 30, 1941, is shown in figure 12. The precipitation varied from a maximum of 28.80 inches during the 12-

month period of 1940–41 to a minimum of 16.05 inches in 1935–36. The distribution of precipitation by months is shown in figure 13 for the 11-year period in comparison with the 49-year averages recorded at Pullman, Wash. These data show that an above-normal precipitation was recorded (in the 11-year period) for the 4 critical erosion months of December, January, February, and March, and a subnormal value for most of the summer months.

The relationship of monthly precipitation to soil and water losses from south control plot 13, bare hard fallow, is given in figure 14 and table 26. The maximum monthly runoff occurred in February and the maximum soil loss in March. During the 4-month period from December to March, when nearly three-fourths of the total erosion occured, there was a general increase in soil and water losses although there was a downward trend in precipitation. The higher precipitation in December caused less erosion than the precipitation during the subsequent 3 months. The precipitation in November and March was approximately equal, but the runoff and soil loss in March were 36 and 129 percent greater, respectively, than in November. This indicates that factors other than the total amount of precipitation have an important influence on erosion.

Runoff and soil losses occurred on south control plot 13 as the result of 334 storms during the 11-year period of July 1, 1931, to June 30, 1942. A record of 65 of these storms, each of which caused soil losses in excess of 0.50 ton per acre, is given in table 3 and Appendix, table 27 on the basis of the time of year the storm occurred and the moisture content of the soil when the rain began. These storms caused 65.6 percent of the total soil loss that was recorded from this

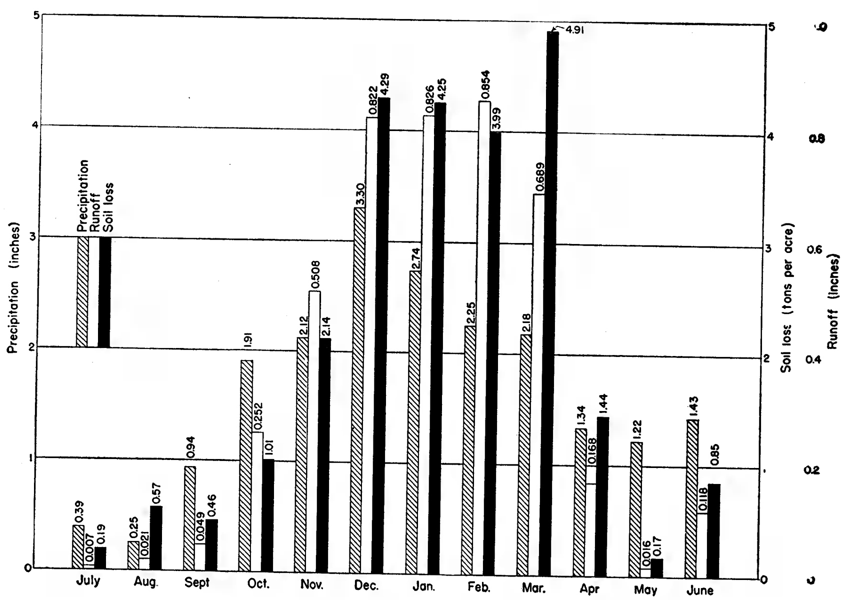


FIGURE 14.—Monthly distribution of precipitation, runoff, and soil loss from bare hard fallow south control plot 13 for the 11-year period July 1, 1931, to June 30, 1942.

TABLE 3.—*Summary of storms which caused soil losses in excess of 0.50 ton per acre from bare hard fallow, south control plot 13, during the period July 1, 1931, to June 30, 1942*

Season that storm occurred	Soil moisture condition when storm began	Storms	Storm characteristics[1]			Runoff in percentage of precipitation	Soil loss	
			Amount	Maximum rate per hour			Per storm per acre	Per inch of rain
				5-minute period	30-minute period			
		Number	*Inches*	*Inches*	*Inches*	*Percent*	*Tons*	*Tons*
Autumn	Moist	11	0.79	0.41	0.21	30.0	1.53	1.94
Winter	Very wet	26	.65	.27	.13	61.0	3.62	5.57
do	Moist	13	.58	.28	.15	31.9	2.43	4.19
Spring	do	7	.37	.58	.25	53.1	2.45	6.62
Summer	Dry	8	.77	1.11	.39	21.6	1.88	2.44

[1] Average values per storm for each group.

plot during the 11-year period. There were 39 storms during the winter months; the others were distributed through the rest of the year.

The 26 winter storms that occurred on very wet soil resulted in the most severe erosion. Water losses were 61.0 percent of the precipitation and soil losses 3.62 tons per acre per storm. The 13 winter storms which fell on moist soil caused about one-half as much runoff and two-thirds as much soil loss per storm although there were no significant differences in the average amount of precipitation or in the maximum rainfall intensities. The autumn rains had greater amounts and significantly higher maximum intensities but resulted in only 30.0 percent runoff and an average of 1.53 tons of soil loss per storm. The spring storms resulted in the smallest amount of precipitation, but the maximum intensities were relatively high, and they caused the second highest erosion losses. Although the summer rains had high maximum intensities, they resulted in low runoff and soil losses from relatively dry soils.

These data indicate that the moisture content of the soil is the most important factor affecting erosion losses in this area. Small winter rains of relatively low intensity falling on wet or saturated soil cause heavy runoff and erosion, while the high-intensity summer rains generally fall on dry soil and result in smaller soil and water losses. Under uniform soil-moisture conditions, the rainfall intensity has a greater influence than the amount of precipitation. It is the high soil-moisture content, resulting from high precipitation and low evaporation, that produces heavy erosion losses during the winter season. Many of the spring storms cause heavy erosion losses on account of their relatively high intensities and the fact that they fall on soil which has become packed and otherwise left in an erodible condition by the winter precipitation.

EFFECT OF PLANT COVER

South control series.—Results from these plots are given for the 10-year period from July 1, 1932, to June 30, 1942. The plots were installed and the cropping system initiated in the spring of 1931, but

the erosion data obtained the first erosion season of 1931–32 is not included in this analysis because the grass seeding was not well established nor were all the crops of the 4-year rotation grown.

The effect of different types of plant covers is shown by the data given in table 4 and figure 15. Grass cover has been found to be the most effective of those tested for preventing runoff and soil loss. The average annual losses have been 0.08 ton of soil per acre and 0.96 percent of the total precipitation lost as runoff. Winter wheat stubble left standing over winter has been practically as effective as grass in controlling soil losses, although the average water losses were higher than for grass. This discrepancy is attributed to the high runoff in the spring of 1933 from snow melting on frozen soil. The standing stubble held a much larger amount of snow than the other plant covers tested. Relatively low soil losses occurred during this runoff period. Soil losses are slightly greater under a spring wheat stubble cover than under winter wheat, since the density of the stand of spring wheat is generally much less than that of fall-seeded wheat.

The wide discrepancy between the soil losses as reported by the reconnaissance erosion survey and those from the control, is accounted

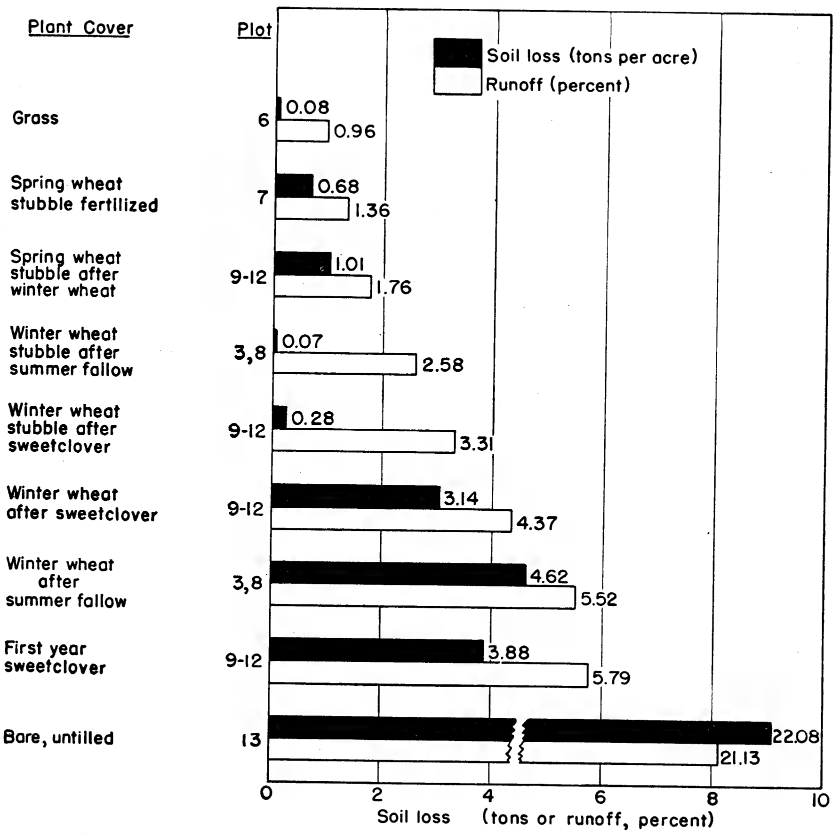


FIGURE 15.—Effect of plant cover on erosion losses from the south control plots for the period July 1, 1932, to June 30, 1942.

for in part by the fact that the control-plot data are confined to relatively short slopes and one soil type, while those reported from the survey include a variety of slope lengths of varying topography and several soil types. Furthermore, the losses from the open fields are augmented by the practice, common in this region, of throwing the furrow slice down the slope each time the land is plowed for wheat. The more rapid melting of deep snow drifts under the influence of warm winds may cause more runoff and soil movement in the open field than in the restricted area of the control plot because the wider variation of slope exposure of the former as compared with the latter.

Erosion is usually severe during the winter immediately following the seeding of winter wheat, especially if seeded on summer-fallowed land. The fallow system as practiced on these plots consists of plowing the crop residues under, and since the wheat makes only a scanty growth during the fall growing season, the soil is left with an inadequate vegetal cover during a period when heavy rains are likely to occur. Wheat seeded on sweetclover land is also deficient in vegetative protection during this period. The average annual soil loss from the winter wheat plots has been 3.14 tons per acre following sweetclover and 4.62 tons following fallow. Water losses have been 4.37 and 5.52 percent of the precipitation, respectively.

TABLE 4.—*Effect of plant cover on erosion losses, south control plots*

WATER LOSS IN SURFACE INCHES

Year [1]	Plot 6 (grass)	Plot 7 (summer wheat stubble, fertilized)	Plots 3, 8 (winter wheat stubble after fallow)	Plots 3, 8 (winter wheat after fallow)	Plots 9–12 (winter wheat stubble, after clover)	Plots 9–12 (summer wheat stubble after winter wheat)	Plots 9–12 (winter wheat after clover)	Plots 9–12 (first year sweetclover)	Plot 13 (bare, untilled)
1932–33	1.309	0.693	4.476	2.134	5.247	1.610	3.272	4.276	7.200
1933–34	.002	1.225	.083	5.269	.774	1.480	3.656	4.471	7.076
1934–35	.025	.015	.033	.203	.007	.003	.094	.009	2.294
1935–36	.208	.458	.023	.377	.092	.109	.097	.911	2.649
1936–37	.178	.021	.198	.685	.132	.147	.509	.344	3.465
1937–38	.009	.001	.014	.329	.002	.007	.131	.360	3.601
1938–39	.149	.046	.210	.645	.060	074	.268	.077	4.295
1939–40	.021	.000	.013	.868	.017	.015	.504	.708	4.710
1940–41	.001	.222	.026	.183	.169	.000	.074	.018	3.377
1941–42	0	0	.019	.221	.039	.039	.021	.263	3.097
Average	.190	.268	.510	1.091	.654	.348	863	1.144	4.176

SOIL LOSS IN TONS PER ACRE

Year [1]	Plot 6 (grass)	Plot 7 (summer wheat stubble, fertilized)	Plots 3, 8 (winter wheat stubble after fallow)	Plots 3, 8 (winter wheat after fallow)	Plots 9–12 (winter wheat stubble, after clover)	Plots 9–12 (summer wheat stubble after winter wheat)	Plots 9–12 (winter wheat after clover)	Plots 9–12 (first year sweetclover)	Plot 13 (bare, untilled)
1932–33	0.76	0.45	0.49	1.10	1.04	0.72	3.13	2.43	20.00
1933–34	.00	3.96	.08	29.58	1.60	9.24	23.19	21.87	38.69
1934–35	.00	.02	.01	.10	0	0	.04	0	9.27
1935–36	.01	2.17	0	1.41	0	.11	0	8.16	9.15
1936–37	0	0	.01	.08	0	.01	.95	.11	25 52
1937–38	0	0	0	.12	0	0	.01	1.06	22.72
1938–39	0	0	0	.80	0	0	.01	0	11.88
1939–40	0	0	0	6.91	0	0	3.57	4 87	45.37
1940–41	0	.15	.11	.40	.15	0	.25	0	13.21
1941–42	0	0	0	5.69	0	.02	.26	.31	24.95
Average	.08	.68	.07	4.62	.28	1.01	3.14	3.88	22.08

[1] The data are based on 12-month periods beginning July 1 and ending June 30.

Precipitation (inches): 1932–33, 21.54; 1933–34, 27.04; 1934–35, 18.57; 1935–36, 16.02; 1936–37, 20.12; 1937–38 18.56; 1938–39, 15.38; 1939–40, 16.35; 1940–41, 26.59; 1941–42, 17.58; average 19.76.

A vegetal cover of 1-year-old sweetclover which had been seeded with peas as a companion crop, with the crop harvested for dry peas and the residue returned to the land, did not provide adequate erosion control. The low degree of protection furnished by the clover can be attributed to the poor growth frequently obtained when a companion crop is grown. The average annual erosion loss for this type of cover was 5.79 percent of the precipitation as runoff and 3.88 tons of soil per acre. The effect of a companion crop on the amount of vegetal cover, as measured by soil and water losses, is shown by a comparison of the results obtained from south control plots 4 and 9. No companion crop is grown with the clover on plot 4, which is seeded to clover the same years as plot 9. For the 3 years that sweetclover was planted on these two plots, the average annual erosion losses were 1.91 percent runoff and 0.25 ton of soil per acre on plot 4 as compared to 9.16 percent runoff and 12.27 tons of soil on plot 9. The average annual green weight of the sweetclover turned under the second year of the rotation was 13.9 tons on plot 4 and 4.3 tons per acre on plot 9. There was probably an even greater difference in the actual density of the plant cover furnished in the two cases during the erosion season than is indicated by the data given.

Plot 13, maintained in a bare and uncultivated condition has shown the highest losses of both soil and water. A loss of 22.08 tons of soil an acre annually and 21.13 percent of the rainfall as runoff have been recorded for this condition. This treatment produced a very critical erosion condition in that the moisture in the soil profile was maintained near its maximum moisture-holding capacity at all times; the soil was compacted and no protective cover was provided. Severe channeling of the soil, as shown in figure 16, also contributed to the losses that occurred on this plot.

Three years' data from the crop-rotation series of plots showing the effect of four types of plant covers on erosion is given in table 5.

TABLE 5.—*The effect of plant cover on erosion losses for the 4-year period 1938–42* [1] *(crop-rotation plots)*

Rotation No.	Plant cover during erosion season	Erosion losses: Runoff 1938–39	Runoff 1939–40	Runoff 1940–41	Runoff 1941–42	Runoff Avg.	Soil loss per acre 1938–39	Soil loss per acre 1939–40	Soil loss per acre 1940–41	Soil loss per acre 1941–42	Soil loss per acre Avg.
		Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
10	Alfalfa-grass mixture	0.049	0.003	0.001	0.014	0.017	0	0.01	0	0	0
2, 4, 6, 8	Spring wheat stubble	.071	.026	.002	.027	.032	0	.03	0	.01	.01
1, 3, 5, 7	Winter wheat stubble	.127	.017	.030	.010	.046	0	.01	0	0	0
1, 3, 5, 7	Winter wheat	.273	1.373	.070	.164	.470	.05	13.82	.07	1.75	3.92

[1] The data are based on years beginning July 1 and ending June 30. The rainfall data for these years are: 1938–39, 15.38 inches; 1939–40, 16.35 inches; 1940–41, 26.59 inches; 1941–42, 17.58 inches; average, 18.98 inches.

The results, which are in agreement with those obtained from the south control plots, show that the highest erosion losses occur on land seeded to winter wheat, and the least on established stands of alfalfa and grass. Both winter and spring wheat stubble are very effective in controlling runoff and erosion, but the winter wheat stubble is usually slightly more effective than that from the spring-seeded grain.

FIGURE 16.—South control plot 13, bare and untilled treatment. May 5, 1942.

EFFECT OF CROP ROTATIONS

The wide variation in the effectiveness of different plant covers in the control of soil and water losses indicates the importance of developing a farming system that will provide an adequate vegetal cover or produce a favorable tillage condition during the winter erosion season. It is also essential to provide soil nitrogen and organic matter in sufficient quantities for the maintenance of a satisfactory fertility level and development of a favorable soil structure.

Such a cropping system should include a legume like sweetclover or alfalfa as a soil-building crop. All crop residues should be carefully utilized to furnish an effective protection against erosion during the winter season and to provide plant material for the maintenenace of soil organic matter.

South control plots.—A 4-year rotation, consisting of peas and sweetclover seeded together the first year, sweetclover as green manure the second year, winter wheat, and spring wheat, has been followed on plots 9 to 12, inclusive, since 1931. Four other cropping systems followed on this series of plots consist of grass cut for hay, spring wheat fertilized annually with ammoniam sulfate, winter wheat alternated with summer fallow, and the bare and untilled condition. Wheat stubble was the winter cover following all wheat crops. The effect of these different cropping systems on soil and water losses is shown by the data given in table 6 and by figure 17. The data are divided into two 5-year periods, July 1, 1932, to June 30, 1937, and July 1, 1937, to June 30, 1942, in order to show the cumulative effect of the treatments.

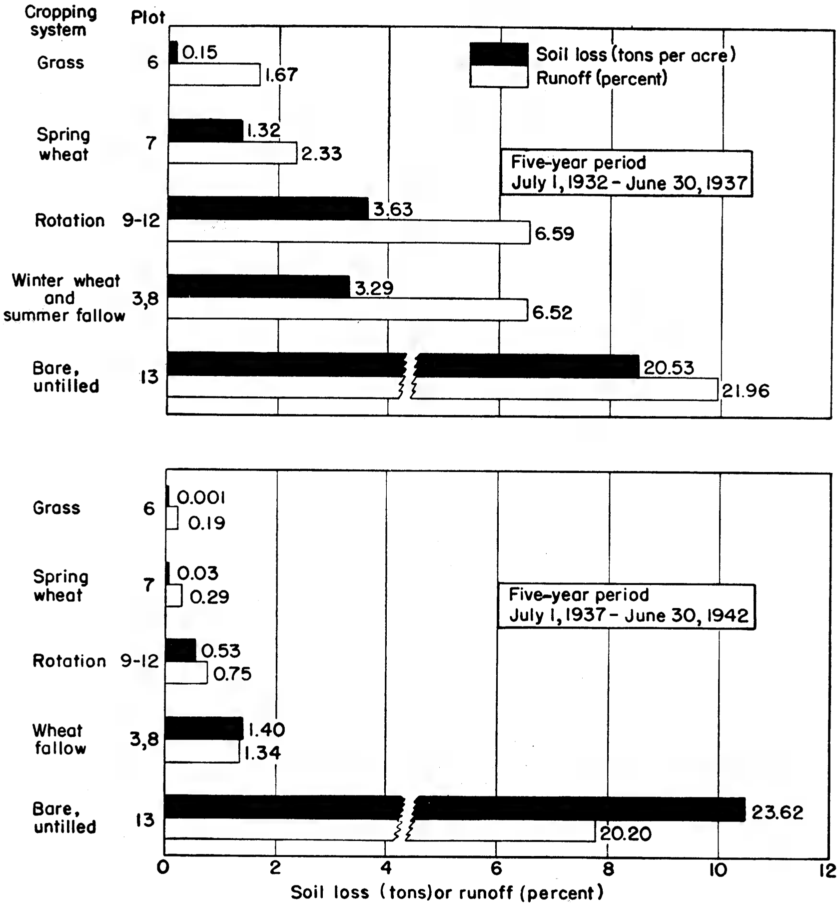


FIGURE 17.—Effect of cropping system on soil and water losses. Average annua values for the south control plots.

TABLE 6.—*Effect of cropping system on erosion losses. Average annual values from south control plots for the 5-year periods July 1932–June 30, 1937, and July 1, 1937–June 30, 1942*

Cropping system	Plot Nos.	1932–37 Runoff Depth	1932–37 Runoff Percentage of precipitation [1]	1932–37 Soil loss per acre	1937–42 Runoff Depth	1937–42 Runoff Percentage of precipitation [1]	1937–42 Soil loss per acre
		Inches	*Percent*	*Tons*	*Inches*	*Percent*	*Tons*
Grass	6	0.344	1.67	0.15	0.036	0.19	0.001
Spring wheat, fertilized	7	.482	2.33	1.32	.054	.29	.03
Rotation	9–12	1.362	6.59	3.63	.142	.75	.53
Winter wheat-fallow	3, 8	1.348	6.52	3.29	.253	1.34	1.40
Bare, untilled	13	4.537	21.96	20.53	3.816	20.20	20.62

[1] Average annual precipitation: July 1, 1932–June 30, 1937, 20.66 inches; July 1, 1937–June 30, 1942, 18.89 inches.

The most effective cropping system for the control of erosion was the maintenance of a grass sod. Spring wheat grown each year and fertilized with ammonium sulfate also gave effective control. During the first 5-year period, the 4-year sweetclover and the winter wheat-summer follow cropping systems had approximately equal erosion losses; but during the second 5-year period, the sweetclover rotation had only 56 percent as much runoff and 36 percent as much soil loss as the wheat-fallow system. This indicates that the use of sweetclover as a green-manure crop has reduced the soil erodibility as compared to the summer-fallow treatment. Severe erosion occurred on the bare and untilled plot during both 5-year periods. However, the water losses from the latter treatment were only slightly less, whereas the soil losses were greater during the second 5-year period than the first.

The effect of sweetclover and summer fallow on erosion from land seeded to winter wheat is shown by the data given in table 7 and figure 18. The results are summarized for three different periods on the basis of the number of crops of sweetclover utilized as green manure.

TABLE 7.—*Comparison of erosion losses from winter wheat seeded after summer fallow and sweetclover. Average annual values from the south control plots*

Period [1]	Winter wheat seeded after summer fallow (plots 3, 8)		Winter wheat seeded after sweetclover (plots 9–12)	
	Runoff	Soil loss per acre	Runoff	Soil loss per acre
	Inches	*Tons*	*Inches*	*Tons*
1932–36 [2]	1.996	8.05	1.780	6.59
1936–40 [3]	.632	1.98	.353	1.14
1940–42 [4]	.202	3.05	.048	.26
1932–42	1.091	4.62	.863	3.14

[1] The data are based on 12-month periods, beginning July 1 and ending June 30.
[2] Each rotation plot had had 1 crop of sweetclover.
[3] Each rotation plot had had 2 crops of sweetclover.
[4] Each rotation plot had had 3 crops of sweetclover.

Sweetclover had been grown once on each of the four plots during the 1932–36 period, twice during the 1936–40 period, and three times on each of the two plots of the 1940–42 period. The average annual soil and water losses were highest in 1932–36, and there was a decrease each subsequent period, except that the soil loss was greater on the summer-fallowed plots during the third period than during the second. Wide variations in the amount of erosion losses from year to year of each period can be attributed largely to climatic factors.

Runoff and erosion was less during each of the three periods on land seeded to winter wheat following sweetclover than from land previously summer-fallowed. Also, the ratio of erosion losses from fallowed land to those from sweetclover land became greater for each succeeding period, indicating that each additional green-manure crop of sweetclover reduced the erodibility of the soil as compared with summer-fallow practice. It appears that the protective effect of several crops is cumulative. During the period from July 1, 1932, to June 30, 1936, when each of the rotation plots had had one green-manure crop, the average annual soil loss from these plots was 6.59 tons per acre as compared to 8.05 tons from the summer-fallowed land. After three crops of sweetclover, however, soil loss was only 0.26 ton per acre as

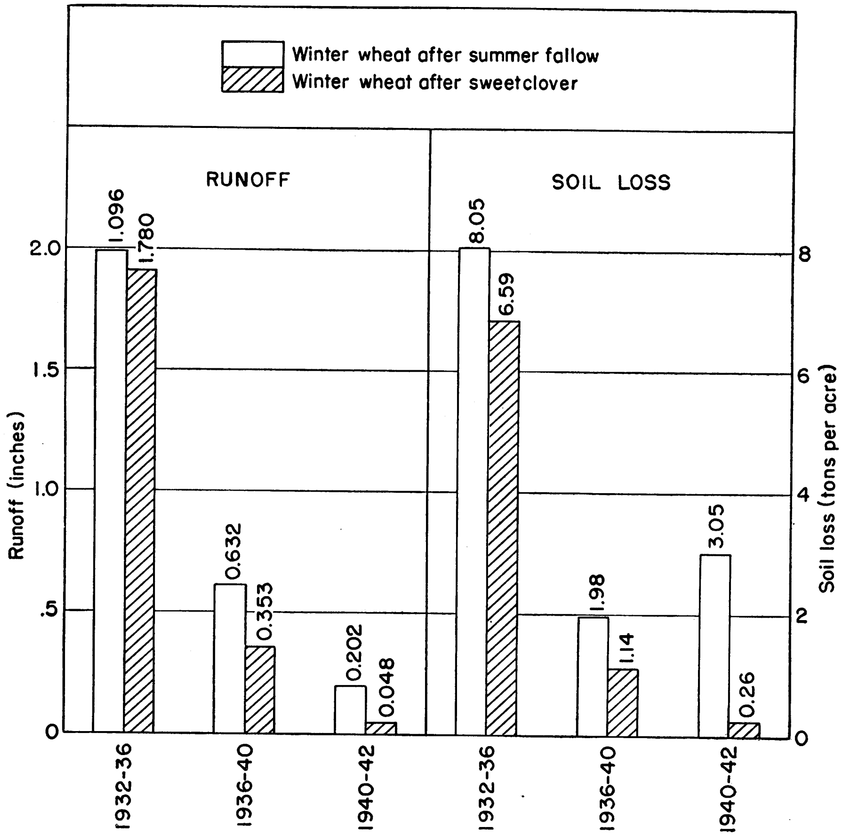


FIGURE 18.—Comparison of erosion losses from summer-fallow and sweetclover land seeded to winter wheat. Average annual values from the south control plots.

compared to 3.05 tons per acre annually for the same period from the fallowed land.

A comparison of the yield of winter wheat grown on sweetclover land and on summer-fallowed land is given in table 8 and figure 19. The results, summarized as 4-year moving averages, show that sweetclover used as a green-manure crop greatly increased the soil productivity. There has been an increase in the wheat yield from 42.3 bushels per acre for the 4-year period of 1933–36 to 51.9 bushels in 1938–41. A corresponding increase was obtained in the green weight of sweetclover turned under. This factor and the cumulative influence of succeeding crops of sweetclover grown on the land are the principal reasons for the steady increase in wheat yields during the course of the experiment. This particular area of land was not in a high state of fertility at the time the sweetclover-cropping system was initiated in 1931. This increase in yields by these well-tested methods of soil conservation, developed during 11 years of research, has important significance for the entire Palouse, at the present writing, in meeting the wartime demand for greater crop production. It is expected that

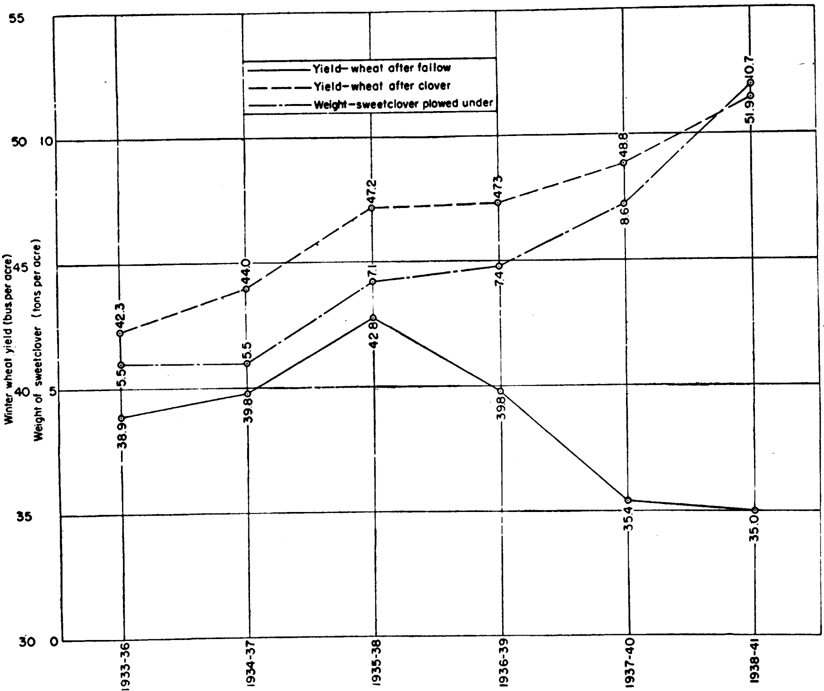


FIGURE 19.—Yield of winter wheat grown after summer fallow and sweetclover plowed under. South control plots.

the present upward trend in yield will soon reach a maximum determined by some other limiting factor, such as soil moisture.

Although the yield of wheat on summer-fallow land has fluctuated widely during the period of the experiment, the trends in yields, together with results of soil-organic-matter analyses and soil and water losses by erosion, indicate that the wheat-summer fallow cropping system is soil depleting, while a rotation including a legume such as sweetclover as a green-manure crop tends to maintain the soil nitrogen and organic matter in sufficient quantities for satisfactory soil fertility and structure conditions.

The results of an analysis of soil samples taken from these plots in 1931 and 1939 show that the practice of summer fallowing reduced the soil organic-matter content at a more rapid rate than the sweetclover cropping system. When the experiment was initiated in 1931, the organic-matter content of the soil on these two groups of plots was was 1.95 percent, and in 1939 the fallowed land had 1.76 percent and the sweetclover land had 1.88 percent organic matter.

There is a direct relation between the weight of sweetclover turned under as green manure and the yield of winter wheat produced on the land. The weight of sweetclover obtained on plots 4, 9, 10, 11, and 12 during the period of the experiment and the corresponding yields of wheat given in table 8 were arranged in order of increasing weights of sweetclover. From this arrangement, four-plot moving averages of weights of sweetclover and wheat yields were calculated and are shown

TABLE 8.—*Winter wheat yield following summer fallow and sweetclover plowed under (south control plots)*

Year	Plot No.	Green weight of sweet clover turned under [1] per acre	Yield of winter wheat		
			Sweet-clover land per acre	Summer fallow land	
				Plot No.	Yield per acre
		Tons	*Bushels*		*Bushels*
1933	4	16.4	50.8	3	44.4
	9	1.7	38.9	3	44.4
1934	12	6.6	41.5	8	22.9
1935	11	4.7	41.9	3	51.3
1936	10	9.0	46.7	8	37.1
1937	4	9.4	45.3	3	48.0
	9	1.5	45.7	3	48.0
1938	12	13.0	54.6	8	34.9
1939	11	5.9	42.0	3	39.3
1940	10	13.9	52.7	8	19.5
1941	4	18.8	63.2	3	46.3
	9	9.8	58.2	3	46.3
FOUR-YEAR MOVING AVERAGE (PLOTS 9, 10, 11, AND 12)					
1933–36	--	5.5	42.3	--	38.9
1934–37	--	5.5	44.0	--	39.8
1935–38	--	7.1	47.2	--	42.8
1936–39	--	7.4	47.3	--	39.8
1937–40	--	8.6	48.8	--	35.4
1938–41	--	10.7	51.9	--	35.0

[1] Sweetclover was turned under during the previous year.

graphically in figure 20. These results show that small crops of sweetclover are only slightly effective in increasing wheat yields, but for amounts greater than about 6 tons per acre, there is a rapid increase in yield for each additional increment of sweetclover utilized as green manure. The curve tends to level off for sweetclover weights in excess of about 12 tons, indicating factors other than the supply of available nitrogen have become limiting. The yields of winter wheat after summer fallow for the same years show that climatic factors have had no significant effect on the trend of crop yields during this period.

Crop-rotation plots.—Runoff and soil losses from the eight 2-year cropping systems for the period July 1, 1938, to June 30, 1942, are given in table 9, and in figure 21. The cropping systems including summer fallow in combination with wheat had the largest soil and water losses, while wheat grown in rotation with Hubam clover as a green-manure crop had the smallest erosion losses. The summer-fallow treatment permitted more than twice as much runoff and four times as much soil loss as the use of Hubam clover. Rotations consisting of wheat alternated with peas harvested for seed or used in a mixture of peas and spring wheat as a green-manure crop, had losses intermediate between the two extremes.

The high losses for the crop year 1939–40 are the result of three periods of heavy precipitation in February and March. Most of the rain during this period had relatively high intensities and fell on saturated or nearly saturated soil. The high erosion losses in the spring of 1940 from plots 12, 18, and 19, which were cropped in 1939 to peas, peas, and spring wheat (under), and Hubam clover (under), respectively, were due to a large extent to the fact that these plots

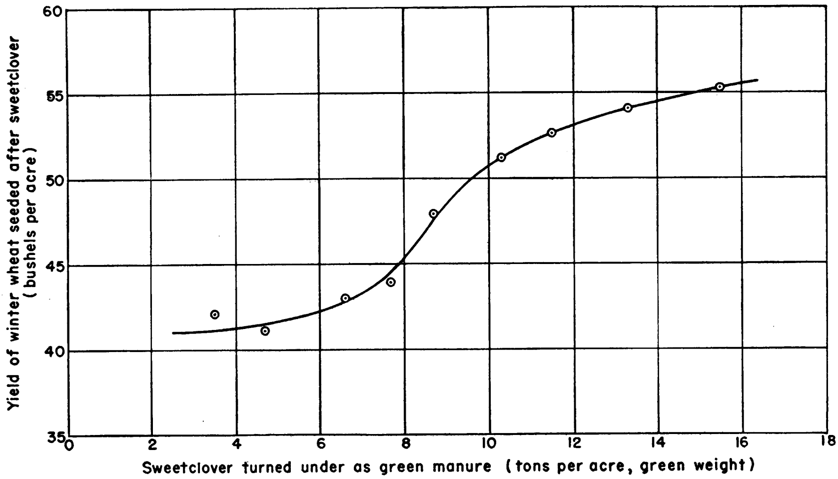


FIGURE 20.—Effect of amount of sweetclover turned under on the yield of winter wheat. South control plots.

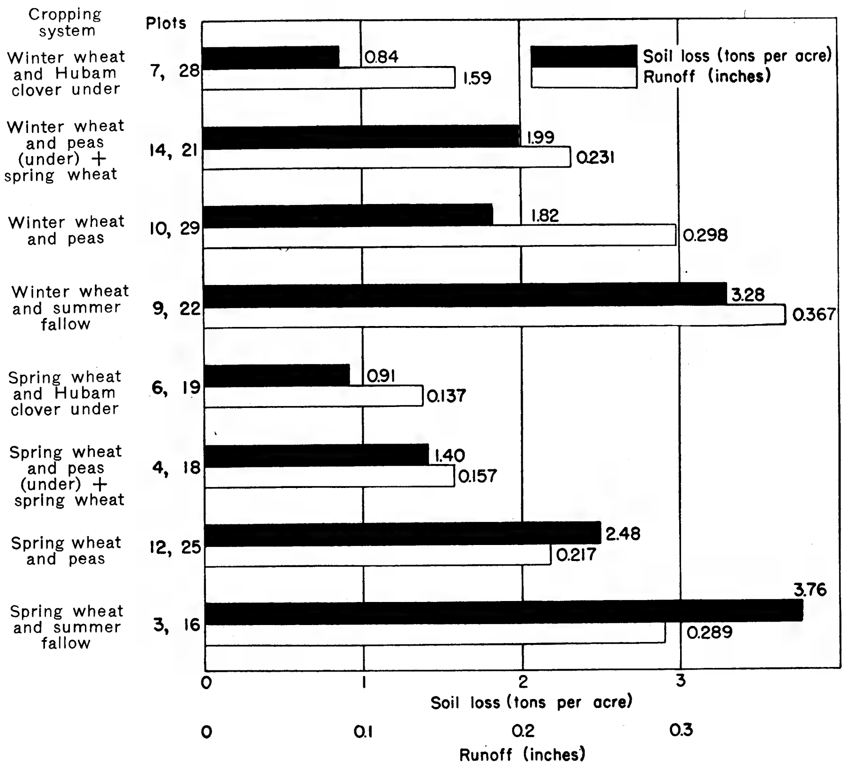


FIGURE 21.—Effect of cropping system on erosion losses. Average annual values from the crop-rotation plots for the period July 1, 1938, to June 30, 1942.

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were fall-plowed up and down the slope. Consequently, the amount of erosion during the 1939–40 season for these three spring wheat cropping systems is considerably greater than would be expected if the usual type of tillage operations had been practiced. Fall tillage operations were conducted on the contour in 1940 and 1941.

TABLE 9.—*Effect of cropping system on erosion losses. Average annual values from the crop-rotation plots for the period July 1, 1938 to June 30, 1942*

Year [1]	Plots 9, 22 winter wheat and summer fallow	Plots 10, 29 (winter wheat and peas)	Plots 14, 21 winter wheat and peas (under) + spring wheat	Plots 7, 28 winter wheat and Huban clover (under)	Plots 3, 16 spring wheat and summer fallow	Plots 12, 25 spring wheat and peas	Plots 4, 18 spring wheat and peas (under) + spring wheat	Plots 6, 19 spring wheat and Huban clover (under)
	Runoff							
	Inch	*Inch*	*Inch*	*Inch*	*Inch*	*Inch*	*Inch*	*Inch*
1938–39	0.159	0.301	0.131	0.209	0.096	0.114	0.019	0.111
1939–40	.918	.753	.738	.372	.501	[2] .713	[2] .471	[2] .307
1940–41	.080	.080	.006	.033	.062	.005	.000	.001
1941–42	.312	.057	.048	.021	.498	.035	.138	.129
Average	.367	.298	.231	.159	.289	.217	.157	.137
	Soil loss per acre							
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1938–39	0.02	0.05	0.01	0.02	0.01	0.04	0	0
1939–40	9.58	7.00	7.81	3.28	7.04	[2] 9.83	[2] 5.26	[2] 3.26
1940–41	.04	.07	.01	.04	.11	0	0	0
1941–42	3.48	.17	.12	.02	7.89	.06	.33	.37
Average	3.28	1.82	1.99	.84	3.76	2.48	1.40	.91

[1] Precipitation (inches): 1938–39, 15.38; 1939–40, 16.35; 1940–41, 26.59; 1941–42, 17.58; average, 18.98.
[2] The furrows were placed at right angles to the contour when the pea land in rotation 4 and the greens manure land in rotations 6 and 8 were plowed in 1938 and 1939. It is believed that the high erosion losses on these plots in the spring of 1940 were caused, to a large degree, by this practice. Contour tillage was practiced in 1940 and 1941.

SOIL ERODIBILITY

The effect of the depth of surface soil and soil organic matter on soil erodibility has been studied at three locations. At the south control series, plot 14 (desurfaced) has not given satisfactorily typical results because the lower level of the plot surface frequently accumulated excess moisture from drifting snow. On plot 15, the layer of clay soil, utilized to replace the original topsoil, has not settled sufficiently to represent a normal condition. The erosion losses from plot 14 have been greater than from check plot 3, but plot 15 has had very little runoff or erosion. The results from this particular series of plots are not considered to be reliable.

College farm plots.—The land that has been cultivated for over 50 years has lost a large part of its organic matter through cropping and erosion losses. An analysis of soil samples taken in the spring of 1942 shows that plots 1 and 2 on the cultivated land have an average of 2.34 percent of organic matter as compared to a 3.89 percent content in the adjacent virgin land. This represents a loss of 40 percent of the original soil organic matter. Plots 1 and 2 on the virgin area had an average organic-matter content of 3.51 percent after being cropped since 1934.

TABLE 10.—*Soil and water losses from virgin land, cultivated since 1934, and from land cultivated for 50–60 years*

[College farm plots]

Year [1]	Winter wheat: Runoff: Depth	Winter wheat: Runoff: Percentage	Winter wheat: Soil loss per acre	Wheat stubble: Runoff: Depth	Wheat stubble: Runoff: Percentage	Wheat stubble: Soil loss per acre	Grass: Runoff: Depth	Grass: Runoff: Percentage	Grass: Soil loss per acre
	Virgin land								
	Inches	*Percent*	*Tons*	*Inch*	*Percent*	*Ton*	*Inch*	*Percent*	*Ton*
1936–37	0.006	0.03	0	0.005	0.02	0.001	0.010	0.04	0
1937–38	.004	.02	0	.003	.02	.001	0	0	0
1938–39	0	0	0	0	0	0	0	0	0
1939–40	0	0	0	0	0	0	0	0	0
1940–41	0	0	0	0	0	0	0	0	0
1941–42	.005	.03	.014	0	0	0	0	0	0
Total	.015	.01	.014	.008	.01	.002	.010	.01	0
	Cultivated land								
1936–37	0.574	2.51	4.337	0.006	0.03	0.004	0.080	0.35	0.010
1937–38	0	0	0	0	0	0	0	0	0
1938–39	1.163	6.74	.203	0	0	0	0	0	0
1939–40	.700	4.31	2.789	0	0	0	0	0	0
1940–41	0	0	0	.023	.08	.087	0	0	0
1941–42	.154	.86	.707	0	0	0	0	0	0
Total	2.591	2.14	8.036	.029	.02	.091	.080	.07	.010

[1] Precipitation (inches): 1936–1937, 22.88; 1937–38, 18.26; 1938–39, 17.26; 1939–40, 16.23; 1940–41, 28.24; 1941–42, 18.05.

Soil and water loss data from the virgin and cultivated areas for the period July 1, 1936, to June 30, 1942, are given in table 10. The winter wheat-summer fallow treated plots (Nos. 1 and 2) are summarized on the basis of the two types of plant cover prevailing during the erosion season, namely, winter wheat seeded on fallowed land and standing wheat stubble. A very small amount of erosion occurred in the virgin land with any of the three types of plant cover. Only 0.01 percent of the precipitation was lost as runoff and 0.014 ton per acre of soil was lost during the 6 years from the winter wheat plot. Erosion losses were small from the wheat stubble and grass plots located on the old cultivated land, but on the winter wheat plot, which had a less effective plant cover, 2.14 percent of the precipitation and 8.04 tons of soil per acre were lost. These data indicate that the higher soil organic-matter content of the virgin land resulted in more rapid infiltration of water and a greater resistance to erosion as compared to the land which has lost a large part of its organic matter. The differences in the structure of the two soils is very striking during the runoff season. The surface of the old cultivated soil breaks down into a decidedly puddled condition, indicating a lack of stable soil aggregates, while a much more porous structure is evident in the virgin soil.

Idaho plots.[4]—The influence on erosion of the application of barnyard manure to the soil is given in table 11 for the 5-year period from July 1936 to June 1941. These plots have been cropped to winter wheat each year since 1915, with plots B–3, D–8, and E–11

[4] The farming operations and the analyses of runoff samples were under the supervision of Mr. G. O. Baker, assistant professor of Agronomy, University of Idaho.

treated with barnyard manure at the rate of 15 tons per acre every third year. The everage annual soil and water losses from the untreated plots have been 0.146 ton of soil per acre and 0.551 inch of runoff as compared to 0.088 ton per acre and 0.303 inch of runoff from the manured plots.

TABLE 11.—*Runoff and soil losses from the rotation plots at the Idaho Agricultural Experiment Station*

Year [1]	With manure [2]							
	Plot B-3		Plot D-8		Plot E-11		Average	
	Runoff	Soil loss per acre	Runoff	Soil loss per acre	Runoff	Soil loss per acre	Runoff	Soil loss per acre
	Inches	*Tons*	*Inches*	*Tons*	*Inches*	*Tons*	*Inches*	*Tons*
1936-37	0.051	0.002	0.003	0	0.015	0.	0.023	0.001
1937-38	.053	.005	.024	.002	.044	.001	.041	.003
1938-39	.224	.005	2.650	.655	1.168	.628	1.347	.429
1939-40	.055	.003	.034	.001	.095	.003	.061	.002
1940-41	.041	.003	.041	.001	.047	.007	.043	.004
Average	.085	.004	.550	.132	.274	.128	.303	.088
	Without manure							
	Plot B-2		Plot D-7		Plot E-10		Average	
1936-37	0.066	0.026	0	0	0.160	0.038	0.075	0.021
1937-38	.126	.009	.023	.002	.022	.002	.057	.004
1938-39	2.036	.349	1.014	.028	4.222	1.707	2.424	.695
1939-40	.165	.009	.155	.007	.175	.008	.165	.008
1940-41	.051	.001	.043	.001	.007	.003	.034	.002
Average	.489	.079	.247	.008	.917	.352	.551	.146

[1] Precipitation (inches): 1936-37, 20.84; 1937-38, 20.16; 1938-39, 16.39; 1939-40, 18.35; 1940-41, 30.36; average, 21.22.
[2] Barnyard manure applied at the rate of 15 tons per acre every third year.

Soil losses from the Idaho plots have been relatively small in relation to the water losses because a very large proportion of the runoff was the result of melting snow, a condition which is conducive to low soil losses. Another factor affecting the low density of the runoff material is the relatively gentle 8-percent slope of the land on the plots.

An analysis of soil samples taken in 1938 shows that the organic-matter content of the manure-treated plots is significantly higher than that of the corresponding untreated areas. The average values for the three plots of each treatment are 2.26 and 1.88 percent, respectively. The effect of the manure is also evident in relation to crop yields. Average yields of winter wheat during the period from 1937 to 1941 were 21.7 bushels per acre for the treated plots and 14.1 bushels for the untreated.

MOISTURE STUDIES

Soil moisture in relation to field conditions.—The absorption of precipitation by the soil is important from the standpoint of obtaining adequate soil moisture for plant growth, as well as for its effect in decreasing the amount of runoff and erosion. This is especially true in the intermountain area of the Pacific Northwest where crops must

depend almost entirely on the water stored in the soil from the winter- and early-spring precipitation, since there is little summer rainfall.

Soil-moisture determinations have been made periodically on the different soils and on land where varied tillage and cropping systems are employed. The results indicate some marked differences in the moisture conditions of different types of soils and in soil handled under varied soil-management practices.

The influence of different crops on the moisture content of the soil at the end of the growing season (August) is shown by the data given in table 12. The samples represent uniform south-slope conditions on which different cropping systems were followed.

TABLE 12.—*Influence of cropping system on the percentage of soil moisture at close of growing season (August)*

Depth of penetration (feet)	Moisture content of soil after—									
	Summer fallow					Winter wheat				
	1934	1935	1936	1937	Average	1934	1935	1936	1937	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	15.8	15.0	14.0	12.2	14.3	11.4	8.5	7.0	9.4	9.1
2	23.4	22.7	23.7	22.2	23.0	14.0	14.8	14.4	13.0	14.1
3	21.8	23.4	26.1	21.9	23.3	14.3	15.5	14.6	14.9	14.8
4	20.0	23.0	23.8	17.1	21.0	15.4	15.8	13.5	13.7	14.6
5	21.2	23.3	23.8	17.4	21.5	18.4	19.0	14.9	14.3	16.7
6	21.2	23.0	22.9	22.3	22.4	18.9	20.1	17.6	17.2	18.5
Average	20.6	21.7	22.4	18.9	20.9	15.4	15.6	13.7	13.8	14.6
	Grass					Alfalfa				
1	7.4	6.6	5.6	7.7	6.8	8.3	7.5	7.5	6.5	7.5
2	12.0	11.9	10.9	13.0	12.0	10.5	11.4	9.3	9.5	10.2
3	13.7	14.7	13.0	13.1	13.6	12.3	13.3	10.9	11.9	12.1
4	13.7	13.4	13.0	13.8	13.5	12.5	12.5	13.1	12.8	12.7
5	14.9	14.0	14.0	17.3	15.1	12.1	11.2	11.4	11.8	11.6
6	16.7	15.7	16.7	18.7	17.0	11.4	11.3	11.2	10.5	11.1
Average	13.1	12.6	12.2	13.9	13.0	11.2	11.2	10.6	10.5	10.9

The results show a high soil-moisture content of the summer-fallowed area as compared to the exceedingly dry condition of the soil on which alfalfa was growing. The average moisture content of the fallowed soil to a depth of 6 feet was 20.9 percent, while alfalfa land contained only 10.9 percent of water. Bunchgrass and winter wheat used moisture to a depth of 5 to 6 feet, but these plants did not reduce the moisture to as low a point as alfalfa. Samples taken in the fall of 1937 in a 6-year-old alfalfa field showed that the moisture was depleted to about the wilting point to a depth of 14 feet, the average moisture content to this depth being 10.7 percent. Some moisture had been utilized to a depth of 17 feet.

During the subsequent winter season only a relatively small amount of rain will be required to bring about a saturated condition in summer-fallowed soil, while the greater moisture deficiency in grass, alfalfa, or wheat land permits the absorption of much more precipitation before saturation occurs. These facts indicate the reasons for the greater runoff and erosion on fallowed land.

The soil and topographic characteristics have a marked influence on the amount of water present in the soil at the close of the season of heavy precipitation. The data given in table 13 show that the moist-

TABLE 13.—*Soil-moisture measurements for different locations on different soil types, 1934–36* [1]

Depth of penetration (feet)	Moisture content of soil on—											
	Palouse silt loam (north slopes) [2]				Palouse silt loam (south and west slopes) [2]				Palouse silty clay loam (eroded hilltops) [2]			
	1934 (10)	1935 (10)	1936 (6)	Average	1934 (5)	1935 (5)	1936 (8)	Average	1934 (6)	1935 (6)	1936 (6)	Average
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1	22.8	23.7	24.2	23.6	19.6	18.5	22.0	20.0	16.3	18.8	18.0	17.7
2	24.5	28.8	30.2	27.8	22.1	25.6	25.5	24.4	17.7	21.2	22.1	20.3
3	26.7	29.7	29.8	28.7	24.1	25.4	24.6	24.7	18.0	19.0	21.1	19.4
4	25.3	27.2	27.7	26.7	21.4	23.2	22.2	22.3	17.4	19.1	21.7	19.4
5	23.9	24.5	24.4	24.3	21.9	22.2	20.7	21.6	19.7	20.9	21.6	20.7
6	23.5	23.3	22.6	23.1	23.5	22.8	20.0	22.1	19.9	20.2	20.5	20.2
Average	24.5	26.2	26.5	25.7	22.1	23.0	22.5	22.5	18.2	19.9	20.8	19.6

[1] Samples taken in May 1934 and 1935, and April 1936.
[2] The numbers in parentheses below the years indicate the number of locations from which samples were taken.

ture content of the surface 6 feet of soil is highest on the steep north slopes and lowest on the eroded hilltops. South and west slopes have a soil-moisture content intermediate between these two extremes. The upper 6-foot section on the north slopes is usually at the maximum field moisture-holding capacity in the early spring, while dry soil is frequently found above the sixth foot on hilltops that were cropped the previous season.

This variation in soil moisture is the result of differences in the infiltration rates of the surface soil, the amount of effective precipitation, and the evaporation from the soil surface in the three locations. The deep friable surface soil on the north slopes absorbs water rapidly, while on the eroded shallow soil, absorption is much slower and more of the precipitation is lost as runoff. The greater effective precipitation on the north slopes is the result of snow blowing off the hilltops, and to a smaller extent from the south and west slopes, and accumulating in drifts on the north slopes. Evaporation from the soil surface is lowest on the north slopes because of lower temperatures and less wind movement.

The hilltop tree planting has had a marked effect on the amount of water absorbed by the soil. In the fall of 1936 the soil moisture had been depleted approximately to the wilting point to a depth of 12 feet where trees were grown and to 8 feet on a hilltop planted to alfalfa. The precipitation during the winter of 1936–37 consisted of a large proportion of snow, which drifted very extensively. Sufficient snow was held in the tree area to cause the moisture to penetrate during the winter and spring season to a depth of 9 feet. It was calculated that 30.9 inches of water was absorbed by the soil. On the alfalfa area, where most of the snow blew off, it was found that the moisture penetrated only 2 feet deep and only 7.1 inches of water was absorbed.

TABLE 14.—*Soil-moisture measurements at terrace 17 for different seasons and locations*

[10 feet east profile, line F]

Depth of penetration (feet)	Moisture content of soil after—				
	Winter wheat	Summer fallow		Winter wheat	
	September 1934	May 1935	September 1935	April 1936	August 1936
35 FEET ABOVE TERRACE CHANNEL					
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1	12.9	22.5	14.0	21.3	5.9
2	13.1	22.4	21.3	23.6	10.5
3	14.7	21.9	21.3	23.2	12.9
4	14.1	20.5	20.5	21.5	12.4
5	13.1	20.9	20.4	22.0	12.0
6	14.8	21.1	20.3	20.2	12.5
Average	13.8	21.6	19.6	22.0	11.0
IN TERRACE CHANNEL					
1	14.1	19.5	17.5	20.4	10.9
2	18.0	21.1	21.0	21.0	13.9
3	17.1	20.7	20.6	22.2	15.1
4	17.4	20.1	20.2	21.1	15.4
5	20.1	23.0	19.9	22.4	17.6
6	21.0	25.2	19.8	24.8	20.9
Average	18.0	21.6	19.8	22.4	15.6
ON TERRACE RIDGE					
1	9.8	17.4	9.6	21.0	5.2
2	8.3	18.5	15.4	24.5	6.9
3	9.9	19.4	18.2	23.2	9.1
4	11.8	18.4	18.1	21.6	10.7
5	12.9	13.4	14.8	19.5	12.6
6	13.0	13.5	13.2	14.4	12.0
Average	11.0	16.8	14.9	20.7	9.4
10 FEET BELOW TERRACE RIDGE					
1	9.8	19.0	17.0	15.2	5.2
2	11.2	20.5	21.6	21.3	7.4
3	13.1	20.2	20.1	20.6	10.4
4	13.4	18.8	20.7	20.5	13.1
5	13.6	16.1	17.9	20.4	12.5
6	13.6	14.1	17.9	19.9	13.5
Average	12.5	18.1	19.2	19.7	10.4
30 FEET BELOW TERRACE RIDGE					
1	11.8	20.6	17.2	17.6	5.0
2	10.7	21.1	22.3	22.8	8.7
3	10.5	20.3	23.2	22.1	10.2
4	14.1	20.1	24.0	22.3	12.7
5	13.8	20.9	24.1	21.0	12.2
6	15.7	20.2	20.6	21.9	14.6
Average	12.8	20.5	21.9	21.3	10.6

The distribution of soil moisture on terraced land is shown by the data in table 14. Samples were obtained in the fall of 1934, spring and fall of 1935, and spring and fall of 1936 at terrace 17. The terrace channel contained the largest amount of moisture, the spring average

for the 6-foot depth being 22.0 percent. The high content in the fifth- and sixth-foot layers indicates that considerable leaching may occur at this place. There was a lower absorption of moisture on the terrace ridge than in the channel or in the terrace interval. The average percentage of moisture on the ridge in the spring was 15.2 for the fifth- and sixth-foot layers as compared with 21.1 percent at the same depth on the undisturbed soil 35 feet above the terraces. The absorption of moisture on the down-slope side of the terrace ridge was also low. There appeared to be practically no lateral movement of moisture on this part of the south slope.

Tillage Practices

Tillage is an important factor in crop yield, weed control, cost of production, and erosion. Frequently in the past the effect of tillage operations on erosion has not been fully considered. Tillage provides mechanical resistance to erosion by means of plant material mixed with the soil and from obstructions it introduces, such as holes, clods, or furrows; and it affects the soil structure, the rapidity with which the soil will absorb water, and the water-holding capacity of the soil.

Utilization of crop residues.—Wheat stubble is the principal type of crop residue available in the Palouse region for use in erosion-control practices. It offers considerable mechanical resistance to erosion, both when standing and when left on the surface as a mulch or mixed with the top layer of soil. Crop residue utilized in this manner maintains a higher infiltration rate by reducing the degree of puddling of the soil surface. The presence of a large amount of organic colloidal material in the soil, resulting from decomposed residues, is an important factor in the maintenance of a granular soil structure and a high water-holding capacity. These desirable soil characteristics decrease runoff and soil losses.

Available nitrogen in the soil is necessary for the proper decomposition of highly carbonaceous material, such as wheat straw, and the amount of nitrogen present determines to a great extent the quantity of such material transformed into soil humus. The incorporation of wheat straw with the soil is likely to reduce the amount of nitrogen available for plants, and since this nutrient is generally the most frequent limiting factor in crop production in this area, crop yields are frequently lower on land where straw was returned than where it was burned.

The effect of stubble utilization and nitrogen fertilization on yields of wheat, grown on land cropped to wheat each year, are given in table 15. The yields where straw was burned were higher than where straw was returned for all three levels of nitrogen fertilization, the average of all plots being 20.4 and 18.4 bushels per acre, respectively. An application of ammonium sulfate gave a marked increase in the yield of wheat. The plots with no fertilizer had an average yield of 13.4 bushels per acre while 80 pounds of fertilizer increased the yield to 19.9 bushels, and 160 pounds to 24.9 bushels. These results show the effect of returning straw to the soil and indicated that the practice has an important influence on the balance of available nitrogen in the soil. It is generally considered that the depression of nitrate production by wheat straw is less on soils with a high organic-matter content or where legumes such as alfalfa or sweetclover have been grown. If

the stubble is utilized effectively to control erosion, the reduction in the rate of soil depletion from erosion losses will probably counterbalance the depression of nitrification, especially if a cropping system including certain legumes is followed.

TABLE 15.—*Effect of stubble utilization and nitrogen fertilizer on yields of winter wheat (bushels per acre). Stubble-utilization plots—field 6*

Treatment	1937	1938	1939	1940	1941 [1]	Average
Straw returned	11.7	12.0	17.3	12.7	8.3	12.5
Straw burned	11.5	15.1	20.8	17.7	7.0	14.4
Straw returned+80 pounds fertilizer [2]	16.4	25.8	27.1	14.6	9.0	18.6
Straw burned+80 pounds fertilizer	19.5	30.4	28.4	18.2	9.7	21.2
Straw returned+160 pounds fertilizer	21.4	34.1	31.6	24.5	10.0	24.3
Straw burned+160 pounds fertilizer	19.5	34.8	37.4	23.3	12.2	25.5
Averages of all plots:						
Straw returned	16.4	24.0	25.3	17.3	9.1	18.4
Straw burned	16.8	26.8	28.9	19.7	9.6	20.4
No fertilizer	11.6	13.6	19.1	15.2	7.7	13.4
80 pounds fertilizer	18.0	28.1	27.8	16.4	9.4	19.9
160 pounds fertilizer	20.5	34.5	34.5	23.9	11.1	24.9

[1] Spring wheat planted in 1941.
[2] Ammonium sulfate per acre applied in the fall.

A program to utilize crop residues for erosion control involves the development of tillage implements designed to leave the residue on or near the surface of the soil and to operate satisfactorily through it during cultivation and seedbed preparation. In order to make the tillage implements operate successfully the stubble is frequently burned, and thus a fiber material is lost which could have been effectively utilized in reducing erosion.

Moldboard plows should have good clearance below the beam to operate successfully in heavy stubble. Many of the ordinary tractor plows do not have sufficient clearance, but this can be corrected by setting the frog lower on the beam and bolting on a ½-inch steel plate to add stiffness. This was accomplished on the 3-bottom, 16-inch plow shown in figure 22. The clearance was increased from 22 to 26 inches, which greatly improved the operation of the plow in heavy stubble or for turning under sweetclover.

Certain changes in the design of moldboards have been tested in order to develop an implement that will leave a part of the stubble on the surface of the soil. By varying the width and curvature of the moldboards, almost any degree of coverage of stubble can be obtained. One such set of moldboards is shown in figure 22. More stubble is left on the surface as the moldboards are made narrower. One objection to this implement is that it is not possible to make adjustments to leave the desired amount of stubble on the surface for different conditions of slope and stubble density. Turning the furrow slice downhill will result in more complete coverage than if it is turned uphill. Similarly, more stubble is left on the surface when heavier stubble is plowed. In most fields in the problem area a wide variation exists in the degree of land slope and stubble density.

An adjustable hinged moldboard plow, shown in figure 23, was developed to provide a means of easily regulating the proportion of crop residue left on the surface. The moldboards on an 18-inch, 3-bottom plow were cut with an acetylene torch diagonally from the heel of the share to a point adjacent to the beam. The two parts were hinged together so as to permit the rear part to swing back against the

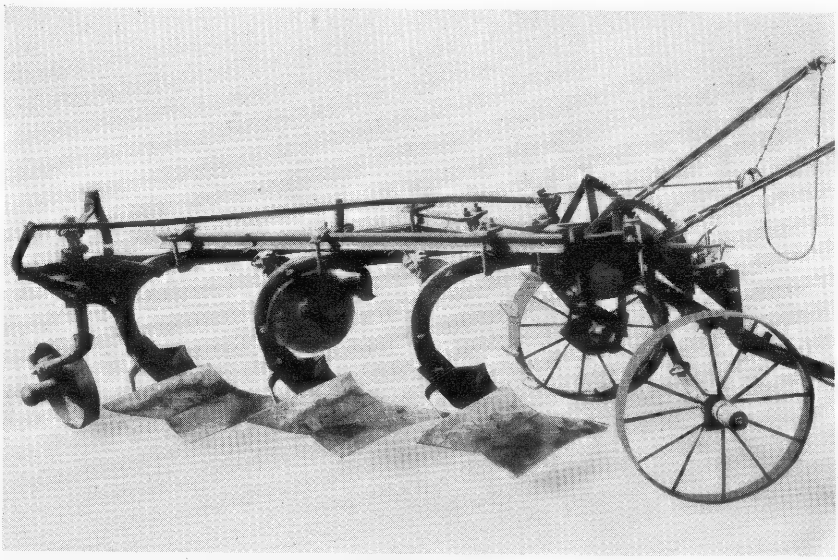

FIGURE 22.—Three-bottom, 16-inch plow rebuilt to give 26-inch clearance below beam and equipped with experimental moldboards 6 inches wide.

beam. A system of levers attached to the movable part allows the tractor operator to set the moldboards in the desired position while the plow is in motion and to make further adjustments to correct for variations in stubble height and density, land slope, and tractor speed. With the hinged part of the moldboards in the extreme rear position, very little of the crop residue is covered and the soil surface is left in a rough and cloddy condition.

Fall plowing of stubble land with a modified moldboard plow leaves sufficient residue on the loose, cloddy surface, to furnish adequate erosion control under most conditions during the winter runoff season. This type of tillage operation is best adapted to the annual cropping system commonly practiced in the higher rainfall sections of the Palouse region. In an annual cropping system, stubble land is usually seeded to a legume the following spring and it is an advantage to have a type of fall tillage that will permit ready seedbed preparations. Where the stubble is heavy, a large portion of it should be brought in contact with the soil to facilitate partial decomposition before spring tillage work is started.

The one-way disk plow, having 26-inch disks with 10-inch spacing, is satisfactory for operation where there is heavy stubble. This implement can be used successfully under conditions where an ordinary 14-inch gang plow cannot be operated. The stubble is mixed with the soil and some left on the surface, leaving the soil much less susceptible to erosion than where the stubble is burned before plowing. The one-way disk plow may also be used for turning under green-manure crops.

It is a common practice to allow wheat stubble to stand over winter when the land is to be summer-fallowed, except that a light tillage operation such as disking may be performed in the fall if the stubble is tall and heavy. This tillage reduces the amount of stubble to be

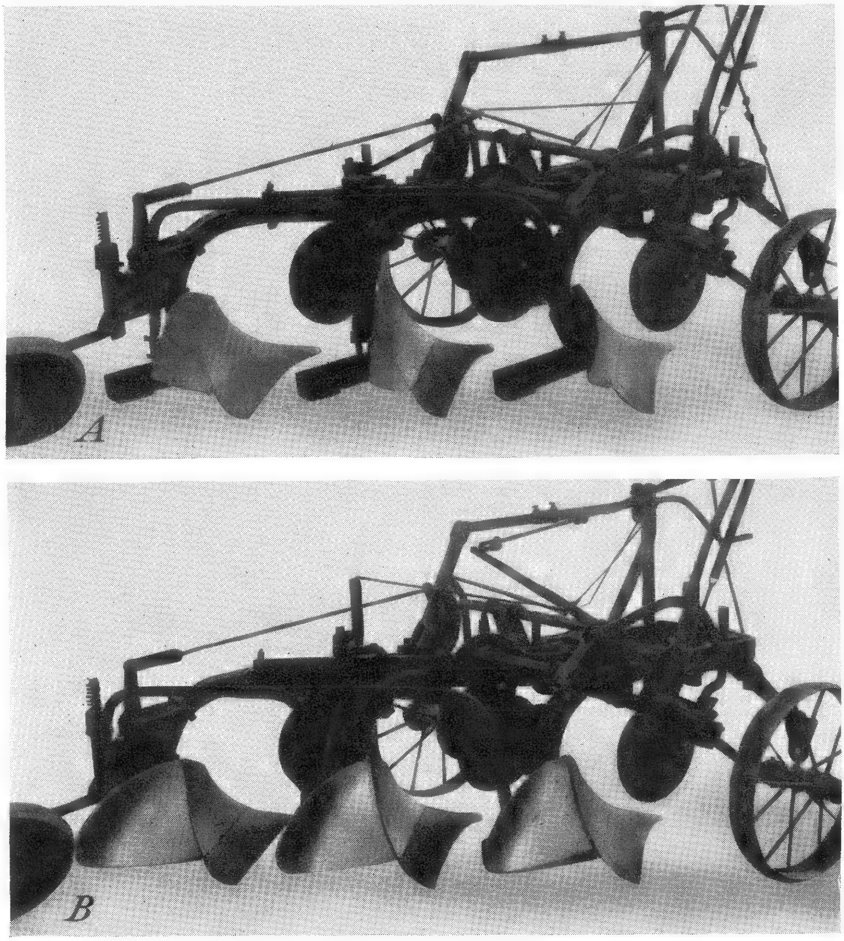

FIGURE 23.—Three-bottom, 18-inch plow equipped with adjustable hinged-type moldboards. *A*, Moldboards in the forward position; *B*, in the rear position.

handled during the summer-fallow season, but leaves enough for effective erosion control if it is utilized as a surface mulch.

In using the combine-harvester the straw is frequently left in a windrow or in bunches. It is difficult to operate a plow in such a field unless the stubble is first burned. Even if a tillage implement can operate, it is believed that these concentrations of stubble are objectionable. It thus seems that if the stubble is to be utilized, it should be spread fairly uniformly over the field by means of straw scatterers attached to the combine-harvesters. This permits the operation of tillage implements in fields having heavy stubble.

It is important that all tillage be on the contour so far as is practicable. Contour tillage has been practiced to a large extent on the steeper lands since the fields were first plowed, but on lands not so steep the tillage is frequently parallel to the section line.

On steep slopes (above 20 percent) the tillage implements will not turn the furrow uphill, and all tillage gradually moves the topsoil down the slopes. During the last 50 years it is likely that at least 6 inches of topsoil has been moved a distance of not less than 25 feet. This condition along with erosion has caused the subsoil to be exposed on many hilltops and upper slopes. No practical method has yet been worked out to stop the soil from moving down the steep slopes so long as cultivation is continued. The use of more perennial crops on these steep slopes and fertilization or cultural practices for building up the soil are believed to be the best means of minimizing the effects of this soil movement.

Special tillage implements.—Two implements, the hole-digging cultivator and the basin lister, were tried on the station on slopes of from 5 to 40 percent. These implements were designed to form small depressions in the soil surface for the purpose of retaining the runoff material until the water is absorbed by the soil. The sloughing in of the holes on account of the steepness of the slopes and weathering reduced the capacity to such an extent that they were only slightly effective. This type of practice is not satisfactory on winter wheatland because if the operation is done before seeding the wheat, the depressions will be partly eliminated by the drill, and if the tillage is done afterward the stand and yield of wheat will be reduced.

Deep tillage.—Plot 5 of the control plots was subsoiled 16 inches deep with a chisel spade at the time of plowing in the spring for summer fallow. The soil loss for this plot was 4.06 tons per acre annually as compared with 4.43 tons for plot 8 where ordinary tillage was practiced. The average runoff from the deep-tilled plot was 5 percent compared with 6 percent for the check plot. The results have varied considerably for different years and the differences are of no practical significance. Much of the effectiveness of deep tillage is lost when the operation is performed in the spring, because the soil is not dry enough to cause the plow-sole to break up sufficiently. This can be accomplished more effectively if the tillage is done in the fall when the soil is dry.

A deep-tillage implement was used in the fall at a depth of 10 inches, and in the spring the disk harrow was used both in seedbed preparation and for summer fallow. This practice leaves considerable stubble either on the surface or mixed with the surface soil, making the soil much less susceptible to erosion than when crop residues are burned, or when the field is plowed so as to bury the stubble completely. Either a regular chisel implement or a plow, with the bottoms removed and chisel points bolted to the beams, is suitable for this type of work. Very favorable reports have been received from certain areas where the chisel was operated in the fall, following crops of peas or wheat, in preparation for spring crops of wheat or peas. If a crop residue on the surface is fairly light, a seedbed can be easily prepared the following spring, but this is more difficult with heavy stubble.

Terracing Studies

Comparison of the amount of material removed by erosion from terraced and unterraced areas serves a valuable purpose in indicating the effectiveness of control by terracing. It should be clearly recog-

nized, however, that under the present experimental technique, the two measurements are not precisely comparable. Records of losses of soil from the ends of terraces are very useful in comparing the effectiveness of terraces of different types, size, and gradient. However, in comparing such records the surface configuration of the interterrace area, and the distances between the terrace ridges, must be taken into consideration.

The unterraced areas are measured as closed watersheds, that is, there is no way for the eroded material carried to the lower part of the area to escape except through the measuring device. The drainage areas formed by the terrace ridges (the interterrace areas) are, however, not entirely closed; that is to say, a considerable portion of the soil eroded from the upper parts of these interterraced areas is deposited in the terrace channel and does not pass on with the runoff through the measuring devices at the ends of the terrace. It is, of course, also true that a part of the eroded material on an interterrace area is deposited on the lower part of the field slope and does not pass off with the runoff through the measuring device. Under some systems of terrace maintenance, part of the soil deposited in the channel is periodically moved up and over the terrace ridge From the lower side of the ridge this is eventually eroded into the next terrace channel downslope. Over a long period this cycle of erosion, deposition, and transposition through maintenance operations usually is repeated many times. As a result, a continuing downslope movement of soil takes place, varying in amount from an insignificant minimum on gently sloping soils of favorable porosity to a serious maximum on steep, highly erodible soil of low absorptive capacity. Obviously, this movement is not measured by the devices placed at the end of the terrace channels.

The magnitude of the loss occasioned by the tranverse movement of soil over the terrace ridges is difficult to measure and, as yet, has not been determined. Through the adoption of a maintenance system in which the soil deposited in the channel is plowed upslope, the soil movement by erosion across the terrace interval may be greatly reduced; and, of course, good rotations, the use of seasonal cover crops, strip cropping, and other soil-stabilizing measures still further reduce the losses.

The use of terraces is conditioned by a large number of factors, such as farming practices and equipment, climate, topography, soil, and cost. In the Palouse area the farms are in general large, many being from 500 to 1,000 acres. Nearly all the fields in the farming section where the station is located have some cultivated slopes as steep as 40 percent, and slopes of 45 to 50 percent are common. Terraces are new in the Pacific Northwest and have been used on only a small number of farms.

The drifting of snow introduces a problem (fig. 24). The snowdrifts sometimes form across the channel, and if runoff occurs the water may flow over the terrace ridge. This occurred a few times during the winters of 1931–32 and 1932–33, but not during the following years of the experiment. The damage caused by such overtopping of graded terraces was slight after the terraces were settled, as the amount of runoff was small. The snow obstructs the flow in the terrace channel to a considerable extent, thus retarding the runoff, and allowing considerable time for the water to be absorbed. Snow

in the terrace channel frequently prevents the ground from freezing, while the ground at other points without a deep snow cover will freeze and thus be practically impermeable.

The average runoff as measured at the outlets of seven representative terraces (Nos. 2, 4, 5, 6, 7, 17, and 18) was 4.9 percent of the rainfall as compared with 19.9 percent for an adjacent unterraced area (W–IV). The soil-moisture determinations show also that the terraces may have reduced the surface runoff, as the moisture content is higher at the terrace channel than at other points (table 14). This has not resulted in increased yields at this point, however, because of removal of topsoil from the channel in constructing the terrace, and possibly other factors, such as leaching and puddling of the soil. There appears to be but little lateral movement of moisture at the

FIGURE 24.—Snow and ice in the channel of terrace 6, December 26, 1932.

location where samples were taken, as the moisture content is lowest below the ridge and on the down-slope side from the ridge.

The average annual soil loss for the seven terraces was 1.09 tons per acre, as measured at the end of the terrace channels, compared with 8.70 tons for an adjacent unterraced area (W–IV). In addition to these measured soil losses, there is some soil movement down the slope from both erosion and tillage. This movement is being studied by means of precise survey measurements, but records over longer periods are needed to determine the extent of movement.

Terrace spacing.—Four terraces, with vertical intervals of 25, 20, 15, and 15 feet are included in the study of terrace design. Each terrace has a length of 780 feet and a uniform grade of 12 inches per 100 feet. The land slope varies from 20.8 to 28.6 percent for the different terraces. During the first year of the experiment one terrace having a vertical interval of 35 feet was included, but the washing between terraces was excessive and an intermediate terrace was constructed. The average annual soil loss at the terrace outlets varies from 0.74 to 1.30 tons of soil an acre (table 16). The terraces on which these two measurements were made all have a 15-foot vertical interval. Detailed records are given in table 30. It is possible that the soil

TABLE 16.—*Surface runoff and soil lost in runoff from graded terraces* [1] *with different vertical intervals, 1931–38*

Period	Total rainfall	Runoff: Terrace 4, 25-foot spacing	Runoff: Terrace 3, 20-foot spacing	Runoff: Terrace 3A, 15-foot spacing	Runoff: Terrace 5, 25-foot spacing	Soil loss per acre: Terrace 4, 25-foot spacing	Soil loss per acre: Terrace 3, 20-foot spacing	Soil loss per acre: Terrace 3A, 15-foot spacing	Soil loss per acre: Terrace 5, 15-foot spacing	Crop
	In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Tons*	*Tons*	*Tons*	*Tons*	
July–Dec. 1931	8.08	0	0	(2)	0	------	------	(2)	------	Peas followed by winter wheat.
Jan.–June 1932	14.18	6.70	[3] 8.18	(2)	7.33	3.92	[3] 4.38	(2)	2.39	Winter wheat.
July–Dec. 1932	10.20	8.43	7.45	5.69	5.88	.02	.02	0.05	.02	Winter wheat stubble.
Jan.–June 1933	11.83	9.72	3.97	14.45	5.16	.07	.03	.51	.03	Stubble disked for fallow.
July–Dec. 1933	16.94	10.98	17.65	24.97	7.32	2.05	4.53	4.60	1.20	Summer fallow seeded to winter wheat.
Jan.–June 1934	10.94	7.77	11.24	19.20	6.67	1.17	2.18	1.80	1.14	Winter wheat.
July–Dec. 1934	9.48	0	0	0	0	------	------	------	------	Disked winter wheat stubble.
Jan.–June 1935	9.56	0	0	0	0	------	------	------	------	Stubble disked for fallow.
July–Dec. 1935	5.50	0	0	0	0	------	------	------	------	Summer fallow seeded to winter wheat.
Jan.–June 1936	10.94	.64	6.00	11.09	10.95	.01	.17	.22	.18	Winter wheat.
July–Dec. 1936	4.03	0	0	0	0	0	0	0	0	Winter wheat stubble.
Jan.–June 1937	16.93	0	0	0	0	0	0	0	0	Stubble disked for fallow.
July–Dec. 1937	10.40	.07	.15	0	.20	.01	.02	0	.11	Summer fallow seeded to winter wheat.
Jan.–June 1938	9.14	1.10	2.34	.67	2.82	.05	.10	.02	.11	Winter wheat.

[1] See table 2 for description of terraces.
[2] Not installed.
[3] 35-foot vertical spacing. Terrace later divided into 3 and 3A.

losses for this experiment were affected to a greater extent by the variations in soil, land slope, and vegetative cover than by the vertical interval. Terrace 3A, having a soil loss of 1.30 tons an acre, is on a 27.1-percent slope and the soil is not so deep as that of terrace 5, which is on a 20.8-percent slope. The fertility of the soil decreases progressively from the lower to the upper portions of the slope. The order of crop yields is the reverse of that of soil losses, the average yield of winter wheat on terrace 5 being 36.2 bushels per acre as compared to 24.0 bushels on terrace 3A.

The average annual soil losses are comparatively low for all the terraces in this experiment, which would indicate that all the vertical intervals are fairly satisfactory. The results from terraces of this experiment and other terraces on the station indicate that a wider spacing can be used where the soil is deep than where the soil is shallow. Based on the measurements of soil losses and on observations of field conditions, the vertical intervals given in table 17 are suggested for graded terraces under the climatic conditions in the wheat-producing area of the Pacific Northwest.

TABLE 17.—*Spacings and grades of terraces recommended for different land slopes*

Land slope (percent)	Grade (fall per 100 feet)	Vertical interval	Horizontal spacing	Land slope (percent)	Grade (fall per 100 feet)	Vertical interval	Horizontal spacing
	Inches	*Feet*	*Feet*		*Inches*	*Feet*	*Feet*
4	1.6	[1] 6.4	[1] 160	18	7.2	14.8	82
6	2.4	[1] 7.6	[1] 127	20	8.0	16.0	80
8	3.2	[1] 8.8	[1] 110	22	8.8	17.2	78
10	4.0	[1] 10.0	[1] 100	24	9.6	18.4	77
12	4.8	[1] 11.2	[1] 93	26	10.4	19.6	75
14	5.6	12.4	89	28	11.2	20.8	74
16	6.4	13.6	85	30	12.0	22.0	73

[1] Where the erosion on the gentle slopes is greater than normal the terraces should be closer together.

Terrace lengths.—Three terraces are included in this study; Nos. 2, 5, and 6, with lengths of 400, 780, and 2,274 feet, respectively Each terrace has a vertical interval of approximately 15 feet and a uniform grade of 12 inches fall per 100 feet. The average land slope is 26.0 percent for terrace 2, 20.8 percent for terrace 5, and 16.8 percent for terrace 6. The summary and detailed records of the annual soil and water losses at the terrace outlet re given in tables 18 and 31, respectively. The soil loss increases with the length

TABLE 18.—*Surface runoff and soil lost in runoff from terraces [1] with different lengths, 1931–38*

Period	Total rainfall	Runoff			Soil loss per acre			Crop
		Terrace 2, 400 feet long	Terrace 5, 780 feet long	Terrace 6, 2,274 feet long	Terrace 2, 400 feet long	Terrace 5, 780 feet long	Terrace 6, 2,274 feet long	
	Inches	*Percent*	*Percent*	*Percent*	*Tons*	*Tons*	*Tons*	
July–Dec. 1931	8.08	0	0	0				Peas followed by winter wheat.
Jan.–June 1932	14.18	6.91	7.33	9.52	1.69	2.39	5.64	Winter wheat.
July–Dec. 1932	10.20	3.53	5.88	14.32	.01	.02	.12	Winter wheat stubble.
Jan.–June 1933	11.83	7.10	5.16	14.96	.04	.03	.06	Stubble disked for fallow
July–Dec. 1933	16.94	14.17	7.32	11.22	2.00	1.20	2.06	Summer fallow seeded to winter wheat.
Jan.–June 1934	10 94	6.03	6.67	6.49	.93	1.14	.82	Winter wheat.
July–Dec. 1934	9.48	0	0	0				Disked winter wheat stubble.
Jan.–June 1935	9.56	0	0	0				Stubble disked for fallow.
July–Dec. 1935	5.50	0	0	0				Summer fallow seeded to winter wheat.
Jan.–June 1936	10.94	.94	10.95	7.94	.01	.16	.05	Winter wheat.
July–Dec. 1936	4.03	0	0	0	0	0	0	Winter wheat stubble.
Jan.–June 1937	16.93	0	0	0	0	0	0	Stubble disked for fallow.
July–Dec. 1937	10.40	0	.20	.02	0	.11	0	Summer fallow seeded to winter wheat.
Jan.–June 1938	9.14	0	2.82	.60		.11	.04	Winter wheat.

[1] See table 2 for description of terraces.

of terrace the comparison being 0.67 ton per acre annually for the 400-foot terrace, 0.74 ton for the 780-foot terrace, and 1.26 tons for the terrace 2,274 feet long. The larger loss for the longer terrace is believed to have resulted from washing in the channel on account of a greater volume of runoff. The loss of 1.26 tons for the longest terrace is not large, however. The average runoff was 5.49 percent from the terrace 2,274 feet long, 3.60 percent for the 400-foot terrace, and 3.85 percent for the 780-foot terrace. The largest amount for terrace 6, which is the longest terrace, is believed to be due to a deeper accumulation of snow over the watershed rather than to any effect of the length of terrace.

This experiment indicates that terraces as long as 2,274 feet are satisfactory. It is believed that the grade used, 12 inches fall for 100 feet, is somewhat more than required on a 16.8 percent land slope. Table 17 indicates that about 7 inches fall per 100 feet is suitable for a 16.8 percent land slope. For terraces more than 1,000 feet in length, it is advisable to provide somewhat larger channel capacity near the outlet than would be needed for shorter terraces.

Terrace grades.—On a graded terrace the water is intercepted as it flows down the slope and is then conducted along the terrace to an outlet. Some of the reasons for using a graded terrace instead of a level terrace with an open end are: Less channel capacity is required;

there is less chance that the graded terrace will break; and water is not so likely to remain in the channel of the graded terrace for extended periods. In order to study the effect of terrace grade, terraces 13, 18, 17, 16, and 15, with grades of level, 6, 12, 18, and 24 inches fall per 100 feet, respectively, were constructed. These terraces are 780 feet long and have vertical intervals of about 14 feet, except terrace 15, which is 685 feet long and has an average vertical interval of 17 feet. The terraces are not entirely comparable because of variations in land slope, soils, and location, but these factors are believed to be of lesser importance than the grades of the terraces. A summary of the soil and water losses for this group of terraces is given in table 19

TABLE 19.—*Surface runoff and soil lost in runoff from terraces* [1] *with different grades 1931–38*

Period	Total rainfall	Runoff					Soil loss per acre					Crop
		Terrace 13, level	Terrace 18, 0.5 percent grade	Terrace 17, 1 percent grade	Terrace 16, 1.5 percent grade	Terrace 15, 2 percent grade	Terrace 13, level	Terrace 18, 0.5 percent grade	Terrace 17, 1 percent grade	Terrace 16, 1.5 percent grade	Terrace 15, 2 percent grade	
	In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	
July–Dec. 1931	8.08	(2)	0	0	0	(2)	(2)	-----	-----	-----	(2)	Peas followed by winter wheat.
Jan.–June 1932	14.18	(2)	5.01	7.69	15.16	(2)	(2)	2.13	5.32	9.27	(2)	Winter wheat.
July–Dec. 1932	10.20	3.33	4.61	3.82	4.51	8.43	0.01	.02	.02	.05	0.08	Winter wheat stubble.
Jan.–June 1933	11.83	7.86	.59	1.27	14.96	21.30	.07	0	.02	.20	.20	Stubble disked for fallow.
July–Dec. 1933	16.94	20.37	19.30	22.31	28.93	34.89	[3] 1.21	3.65	9.03	11.22	13.47	Summer fallow seeded to winter wheat.
Jan.–June 1934	10.94	10.33	13.35	13.89	12.52	18.74	.35	1.24	3.19	3.83	5.30	Winter wheat.
July–Dec. 1934	9.48	0	0	0	0	0	-----	-----	-----	-----	-----	Disked winter wheat stubble.
Jan.–June 1935	9.56	0	0	0	1.15	.73	-----	-----	-----	0	0	Stubble disked for fallow.
July–Dec. 1935	5.50	0	0	0	0	0	-----	-----	-----	-----	-----	Summer fallow seeded to winter wheat.
Jan.–June 1936	10.94	10.29	6.64	5.47	24.51	24.41	.15	.12	.24	.77	1.12	Winter wheat.
July–Dec. 1936	4.03	0	0	0	0	0	-----	-----	-----	-----	-----	Winter wheat stubble.
Jan.–June 1937	16.93	0	0	0	0	0	-----	-----	-----	-----	-----	Stubble disked for fallow.
July–Dec. 1937	10.40	1.39	.10	4.46	22.88	7.00	.04	.01	.15	3.16	1.56	Summer fallow seeded to winter wheat.
Jan.–June 1938	9.14	3.57	1.41	7.49	23.35	23.29	.02	.05	.77	2.34	1.80	Winter wheat.

[1] See table 2 for description of terraces.
[2] Not installed.
[3] Terrace 12 would not hold all of runoff, water overtopped dike at end of terrace 13. The combined areas of 12 and 13 were used for working up data for such periods.

and detailed results in table 32. The average annual soil loss increases progressively as the grade increases, the loss ranging from 0.33 ton an acre for a level grade to 4.26 tons (6-year period) an acre for a fall of 24 inches per 100 feet. Terrace 16 has a soil loss of 4.41 tons annually for the 7-year period, but the loss is 3.60 tons for the corresponding 6-year period. The runoff follows the same general trend with the exception of the terrace with a level grade. Greater accumulations of snow over the watershed of this terrace resulted in greater runoff.

There was considerable washing in the channels of the terraces with grades of 18 and 24 inches fall per 100 feet and some washing where the fall was 12 inches per 100 feet. Figure 25 shows the erosion in the channel of terrace 15 (24-inch fall) after the runoff season of 1931–32. The indications are that from the standpoint of soil loss and general practicability the grade of 6 inches fall per 100 feet (fig. 26) is the best

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FIGURE 25.—Washing in the channel of terrace 15, fall of 24 inches per 100 feet, April 15, 1932.

FIGURE 26.—Channel of terrace 18, fall of 6 inches per 100 feet, April 27, 1932.

in this group of terraces. The level terrace tends to impound water in the channel and is more likely to overtop. More difficulty is experienced with snow blocking the channels of the level terraces than those of the graded terraces. Because of the difficulty in obtaining channel capacity on the steeper slopes and of the greater tendency for

deltas to obstruct the channel, it is believed that terraces on the steeper slopes should have more fall than those on the flatter slopes. Furthermore, if the terracing machine gets slightly off the line of stakes on a steep slope, a high or low place will occur in the terrace. This is more serious with a level grade or slight grade than where the terrace is given more fall. A fall along the terrace of 6 inches per 100 feet is believed to be about right for a 15-percent slope and this should be increased or decreased about 2 inches for each 5-percent increase or decrease in land slope. The grades of terraces in accordance with this recommendation are given in table 17. The variable-graded terrace is recommended, especially where the terrace is of considerable length. The grade near the outlet should be as given in table 17, and the grade should be proportionately less toward the upper end of the terrace. For the steeper slopes it is advisable to have a slight grade at the upper end rather than to start with a level grade.

Land slope.—Land slope is a very important consideration in land use, and in order to study the use of terraces on different land slopes, four terraces, 7, 5, 17, and 3A, were constructed on land slopes of 13.4, 20.8, 25.2, and 27.1 percent, respectively. Each terrace is 780 feet long, has a uniform grade of 12 inches fall per 100 feet, and a vertical interval of about 15 feet. A summary of the runoff and soil loss is given in table 20. The detailed results are given in table 33. The average annual soil loss through the outlet is 0.17 ton per acre for a 13.4-percent slope, 0.74 ton for a 20.8-percent slope, 2.67 tons for a 25.2-percent slope, and 1.30 tons for a 27.1-percent slope. In general the soil losses are more for the steep slopes than for the flatter slopes, although the soil loss for the 27.1-percent slope was much less than for the 25.2-percent slope. The detailed soil survey (fig. 6) shows

TABLE 20.—*Surface runoff and soil lost in runoff from terraces [1] on different land slopes 1931–38*

Period	Total rainfall	Runoff				Soil loss per acre				Crop
		Terrace 7, 13.4 percent land slope	Terrace 5, 20.8 percent land slope	Terrace 17, 25.2 percent land slope	Terrace 3A, 27.1 percent land slope	Terrace 7, 13.4 percent land slope	Terrace 5, 20.8 percent land slope	Terrace 17, 25.2 percent land slope	Terrace 3A, 27.1 percent land slope	
	In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Tons*	*Tons*	*Tons*	*Tons*	
July–Dec. 1931	8.08	0	0	0	(2)	------	------	------	(2)	Peas followed by winter wheat.
Jan.–June 1932	14.18	14.53	7.33	7.69	(2)	0.74	2.39	5.32	(2)	Winter wheat.
July–Dec. 1932	10.20	21.27	5.88	3.82	5.69	.06	.02	.02	0.05	Winter-wheat stubble.
Jan.–June 1933	11.83	35.93	5.16	1.27	14.45	.06	.03	.02	.51	Stubble disked for fallow.
July–Dec. 1933	16.94	4.25	7.32	22.31	24.97	.28	1.20	9.03	4.60	Summer fallow seeded to winter wheat.
Jan.–June 1934	10.94	1.65	6.67	13.89	19.20	.07	1.14	3.19	1.80	Winter wheat.
July–Dec. 1934	9.48	0	0	0	0	------	------	------	------	Disked winter-wheat stubble.
Jan.–June 1935	9.56	0	0	0	0	------	------	------	------	Stubble disked for fallow.
July–Dec. 1935	5.50	0	0	0	0	------	------	------	------	Summer fallow seeded to winter wheat.
Jan.–June 1936	10.94	6.12	10.95	5.47	11.09	.03	.18	.24	.22	Winter wheat.
July–Dec. 1936	4.03	0	0	0	0	------	------	------	------	Winter-wheat stubble.
Jan.–June 1937	16.93	0	0	0	0	------	------	------	------	Stubble disked for fallow.
July–Dec. 1937	10.40	0	.20	4.46	0	------	.01	.15	------	Summer fallow seeded to winter wheat.
Jan.–June 1938	9.14	.05	2.82	7.49	.67	0	.11	.77	.02	Winter wheat.

[1] See table 2 for description of terraces.
[2] Not installed.

that more subsoil is exposed on terrace 3A than on 17 and that terraces 5 and 7 have productive surface soil over nearly the entire drainage area. In general the thin soil erodes more than the deeper soil. However, where the subsoil is exposed it appears that the erosion is less than where there is a thin layer of surface soil, although the percentage of runoff is greater. The measured runoff was greater from terrace 3A, even though the soil loss was less.

The percentage of runoff in this experiment has no very apparent relation to either the land slope or soil loss. But there are certain factors which should be explained. The runoff from a land slope of 13.4 percent was 6.79 percent of the average precipitation, which is more than that from slopes of 20.8 and 25.2 percent, but less than that from the 27.1 percent slope. This condition is believed to be due largely to a variation in the depth and accumulation of snow over the watershed. The snow usually has been much deeper on the lower slope, and even though the runoff was greater on the more gentle slope than on some of the slopes above, it is almost certain that the amount of water absorbed by the soil was also greater.

Terraces were more satisfactory on slopes below 15 percent than on steeper slopes. On the flatter slopes a broad-base terrace can be readily crossed by farm machinery when necessary. This is much more difficult on the steep slopes. On slopes where the plow furrow can be turned up the slope the tillage equipment can be operated so as to help maintain the terrace. On both terraced and unterraced slopes steeper than 15 to 20 percent, all tillage tends to move the soil down the slope. This movement of soil, along with accelerated erosion, gradually exposes the subsoil on the upper slope. The soil accumulates in the terrace channel and must be moved to the ridge with a terracing machine almost every year the field is cultivated.

Terrace cross sections and their effect on operation of farm machinery.— The type of terrace cross section will vary with land slope, land use, and other factors, such as soil, climate, and machinery used. So far as practical, the terrace should be so constructed as to cause the least inconvenience in the operation of farm machinery, and at the same time it should be of sufficient capacity to avoid overtopping. On comparatively gentle slopes, such as one of 5 percent, a wide terrace can be constructed which will not cause any great inconvenience in the operation of machinery. On steep slopes of 20 to 30 percent or more a narrow terrace must be used, and it may be impossible to operate machinery over the terraces. Actual cross sections of terraces on different land slopes show that on slopes of 28 to 30 percent the distance from the center of the ridge to the center of the channel is about 4 feet, and for land slopes of 15 to 17 percent it is about 6 feet. This distance is too short to permit the operation of wide machinery, such as large-size tillage and harvesting implements.

The terrace cross sections on land slopes of 5 and 15 percent have the lower side of the embankment 10 percent steeper than the land slope, and for 25- and 30-percent land slopes, the lower side of the embankment is 15 percent steeper. The wider terraces give a less abrupt terrace embankment, but the amount of soil to be moved becomes very great for slopes of 20 to 30 percent. In order to have a completed terrace with total width of 36 feet and height of about 15 inches it is necessary to cut 24 inches deep on slopes of 25 or 30 percent, and the average cut is about 18 inches over a distance of

12 feet. The total cut is about 18 cubic feet per lineal foot of terrace as compared with 8 and 13 cubic feet on 5- and 15-percent slopes, respectively.

This study indicates that the broad-base terrace, which can be cultivated, is practical on slopes up to about 15 percent, but that for steeper slopes a narrow-base terrace must be used. Although the narrow-base terrace can be cultivated, the work cannot be done readily with large machinery.

Level terraces with closed ends.—Level terraces with closed ends were constructed on different slopes: Terraces 14, 19, and 20, encircle hilltops, terraces 2A, 8, 9, and 10 are on the upper slope where the soil is poor, and terraces 11 and 12 are on the lower slope where the soil is deep and fertile. The runoff on several occasions has greatly exceeded the capacity of most of the terraces, and dikes at the end were lowered enough to permit the excess water to waste and not overtop the terrace.

During the winter of 1932–33 and again in 1933–34, water stood continuously in the channels of terraces 8 and 9 for periods of 4½ months, which, of course, killed the crop of winter wheat. The water in excess of their capacity was wasted at the end. The capacity of all the other terraces was exceeded at some time during the period. The drainage area of terrace 12 is nearly all good soil, and this terrace has prevented the occurrence of runoff from most rains.

During the winter of 1933–34, when runoff was especially large for most areas, terraces 14, 19, and 20, in second-year alfalfa, first-year sweetclover, and winter wheat, respectively, held all of the runoff and absorbed the water without material damage to the crop. In previous years, with a cropping system of wheat-fallow, terraces 14 and 19 had not held the runoff, which indicates that the alfalfa and sweetclover increased the absorptive capacity of the soil. Terrace 20 has never had as much runoff as many of the other terraces, which is likely due to a soil condition.

The experimental data indicate that for the soil and climatic conditions at the station it is not practical to build level terraces to hold all the runoff from bare cultivated land.

Watershed Areas

Runoff and soil loss.—A summary of soil and water losses from the unterraced watershed areas is given in table 21. The lowest average annual runoff was recorded on the 14.4-acre watershed, W–V, and the highest on the 16,700-acre area, W–VII. The larger amount of runoff from the latter watershed may be partly attributed to the fact that about 20 percent of its area is located in the Moscow Mountains where the precipitation and snow accumulation are greater. The data do not show a relationship between the size of the watershed and the quantity of runoff. Factors such as plant cover and cropping practice appear to have a much greater effect than mere size.

The amount of soil carried from a watershed area is affected by the character of the drainage system and the land slope. Where there is relatively level land at the lower portion of a slope, a considerable amount of the soil is deposited and does not pass through the measuring device. The measurements were discontinued in 1938 because this type of soil-loss determination is not an accurate index of erosion on the whole watershed.

TABLE 21.—*Surface runoff and soil loss in runoff from watershed areas of different sizes and characteristics, 1931–41* [1]

Period	Total rainfall [2]	Runoff for period						Soil loss per acre [3]					
		W–IV	W–V	W–VI	W–II	W–VIII	W–VII	W–IV	W–V	W–VI	W–II	W–VIII	W–VII
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
July-Dec. 1931	8.08	[4] 0.41	(5)	(5)	[6] 0.29	(5)	(5)	[4] 0.49	(5)	(5)	[6] 0.03	(5)	(5)
Jan.-June 1932	14.18	[4] 4.58	(5)	(5)	[6] 8.52	(5)	(5)	[4] 22.50	(5)	(5)	[6] 25.07	(5)	(5)
July-Dec. 1932	10.20	[7] 1.46	[6] 0.66	[7] 0.37	1.19	(5)	0.18	[7] .03	[6] 0.05	[7] 0	0.54	(5)	0
Jan.-June 1933	11.83	[7] 5.30	[6] 4.70	[7] 6.84	6.83	(5)	8.48	[7] .30	[6] 9.05	[7] 0.40	4.19	(5)	3.26
July-Dec. 1933	16.94	[6] 5.43	[7] 1.15	[6] 5.19	3.71	(5)	4.58	[6] 10.97	[7] .03	[6] 7.92	3.54	(5)	4.99
Jan.-June 1934	10.94	[6] 1.83	[7] 3.39	[6] 3.18	4.81	(5)	3.64	[6] 2.98	[7] .04	[6] 2.10	1.67	(5)	2.79
July-Dec. 1934	9.48	[7] 0	[6] 1.08	[8] .19	.93	.29	.23	[8] 0	[6] .96	[8] .03	.60	.14	.09
Jan.-June 1935	9.56	[7] 0	[6] 4.28	[9] 2.43	3.03	2.62	4.57	[8] 0	[6] 1.50	[9] .22	.35	.25	.63
July-Dec. 1935	5.50	[6] 0	[8] 0	[10] .09	.02	.01	.02	[6] 0	[8] 0	[10] .09	0	0	0
Jan.-June 1936	10.94	[6] 3.12	[9] 1.07	[10] 2.69	2.06	2.19	2.59	[6] 1.71	[9] .12	[10] 1.46	.18	.45	1.16
July-Dec. 1936	4.03	[7] 0	[4] 0	[6] 0	0	0	0	[8] 0	[4] 0	[6] 0	0	0	0
Jan.-June 1937	16.93	[7] .68	[4] 2.09	[6] 3.81	2.18	1.84	3.91	[9] .01	[4] .82	[6] 2.51	.40	.95	1.09
July-Dec. 1937	10.40	[6] 3.05	[8] 0	[8] .36	.32	.08	.15	[6] 14.85	[8] 0	[8] .22	.02	.02	.01
Jan.-June 1938	9.14	[6] 3.63	[11] .58	[12] .90	2.17	1.71	4.17	[6] 7.04	[11] .02	[12] .03	.10	.19	.45
July-Dec. 1938	6.89	(13)	[8] 0	[8] 0	.20	.01	(13)	------	------	------	------	------	------
Jan.-June 1939	9.71	------	[10] [11] .65	[9] .75	2.68	2.01	------	------	------	------	------	------	------
July-Dec. 1939	6.14	------	[10] 0	[8] 0	0	.01	------	------	------	------	------	------	------
Jan.-June 1940	11.69	------	[10] .56	[9] .98	.77	1.48	------	------	------	------	------	------	------
July-Dec. 1940	14.24	------	[14] .51	[4] 1.05	.25	.46	------	------	------	------	------	------	------
Jan.-June 1941	14.67	------	[14] 2.35	[4] 4.17	.93	2.37	------	------	------	------	------	------	------
Average (1932–38)	20.98	4.08	3.17	4.34	4.54	------	5.42	6.32	2.10	2.50	1.93	------	2.41
Average (1934–38)	19.00	2.62	2.28	2.62	2.68	2.19	3.91	5.90	.86	1.14	.41	.50	.86
Average (1934–41)	19.90	------	1.88	2.49	2.22	2.15	------	------	------	------	------	------	------

[1] Size of watersheds (acres): W–IV, 2.33; W–V, 14–4; W–VI, 15.2; W–II, 68.2; W–VIII, 762; W–VII, 16700.
[2] Recorded by rain gage No. 5 near terraced areas.
[3] Soil-loss measurements discontinued June 30, 1938.
[4] Winter wheat following peas.
[5] Not installed.
[6] Winter wheat on fallow.
[7] Standing wheat stubble.
[8] Stubble fall plowed or disked.
[9] Peas.
[10] Sweetclover.
[11] Flax.
[12] Spring wheat.
[13] Measurements discontinued.
[14] Winter barley.

Soil losses from the watersheds were relatively small except on the 2.33-acre area (W–IV), which has a large proportion of steep land and a drainage system that is conducive to carrying most of the silt past the measuring equipment. This area was also cropped more frequently to the winter wheat-summer fallow cropping system than the other watersheds.

A summary of the results for the three areas, W–IV (2.33 acres), W–V (14.4), and W–VI (15.2 acres) shows the effect of the cropping treatment on runoff and soil losses. During the 4-year period from July 1, 1934, to June 30, 1938, the average annual runoff was 4.53 inches from winter wheatland and 1 inch from stubble land fall-plowed or disked. Soil losses were 6.93 and 0.07 tons per acre, respectively. The erosion season July 1932 to June 1933 was marked by high water but low soil losses as the result of melting snow on frozen soil. For this 1932–33 season watershed W–V, seeded to winter wheat, lost 5.36 surface inches of water and 9.10 tons of soil per acre, while areas W–IV and W–VI, with a plant cover of standing wheat stubble, lost an average of 6.99 inches of water and 0.37 ton of soil. Total annual run-off is usually significantly greater from summer-fallowed land than from land treated with the other common cropping practices.

Runoff from the watershed areas is greater than that from the small control plots and terraces. The average annual runoff from the 5

watersheds for the period July 1, 1932, to June 30, 1938, was 4.31 inches as compared to 1.15 inches for two $\frac{1}{100}$-acre control plots (Nos. 3 and 8) and 1.42 inches from 12 representative terraces. The greater runoff from the larger areas is due to at least 2 factors, namely, the greater accumulation of snow and the presence of ground-water flow. The accumulation of snow is much greater on north slopes, lower slopes, and valleys than on south slopes and hilltops. The older plot installations and most of the terraces are on the upper or middle south slopes and do not have these areas of large snow accumulation. Ground-water flow rarely occurs for terraces and plots on south slopes, but usually continues in the natural drainage courses of the larger areas for several months each year. An attempt was made to separate the ground-water flow from the surface runoff, but the data are not sufficiently complete to make an accurate separation. The indications are, however, that for years of heavy runoff, such as 1932–33 and 1933–34, the surface runoff may be five times as much as the ground-water flow, while for years of moderate to slight runoff, such as 1934–35 and 1935–36, the ground-water flow may equal the surface runoff.

Maximum rates of runoff.—The rates of runoff from the experimental watersheds for the principal storms during the period 1932–41 are given in table 22. In some cases, snow melting at the same time the rain fell, greatly increased the runoff.

TABLE 22.—*Rates of runoff and rainfall for principal storms, 1932–41*

Station	Size of watershed	Date	Maximum rate of runoff		Maximum rainfall rate for period of—				24-hour rainfall	Remarks
			Second feet	*Inch-per-hour*	5 minutes	10 minutes	30 minutes	60 minutes		
	Acres				*In.*	*In.*	*In.*	*In.*	*In.*	
W-IV	2.33	Jan. 11, 1932	0.4	0.17	0.33	0.33	0.30	0.27	0.69	Rain on snow.
	2.33	Mar. 27–28, 1932	.7	.30	.42	.36	.24	.14	.73	Do.
	2.33	Dec. 5–6, 1933	1.0	.42	.48	.36	.20	.20	2.22	Rain.
	2.33	Dec. 22, 1933	[1] 1.1	[1] .47	.72	.42	.14	.10	.79	Rain on saturated soil.
W-V	[2] 14.4	Dec. 21, 1934	2.2	.15	.48	.30	.18	.17	.93	Rain.
W-VI	15.2	Nov. 2–3, 1933	4.5	.29	.48	.36	.22	.19	1.07	Rain on saturated soil.
	15.2	Dec. 5–6, 1933	[1] 6.0	[1] .39	.48	.36	.20	.20	2.22	Rain.
	15.2	Dec. 22, 1933	4.1	.27	.72	.42	.14	.10	.79	Rain on saturated soil.
W-II	68.2	Jan. 11, 1932	[1] 17.0	[1] .25	.33	.33	.30	.27	.69	Rain on snow.
	68.2	Jan. 5, 1933 [3]	12.0	.17	----	----	----	----	[3] .07	Melting snow.
	68.2	Dec. 22, 1933	8.1	.12	.72	.42	.14	.10	.79	Rain on saturated soil.
W-VIII	762	Mar. 7, 1940	31.1	.040	.24	.24	.20	.17	.88	Do.
	762	June 17, 1941	38.0	.049	.48	.42	.26	.17	.45	Do.
W-VII	16,700	Jan. 7–8, 1933	660	.039	.16	.16	.12	.09	.72	Rain on snow.
	16,700	Sept. 9, 1933 [4]	920	.054	----	----	----	----	(4)	Intense rain.
	16,700	Dec. 8–9, 1933	[1] 1,062	[1] .063	.21	.18	.18	.17	1.73	Rain on saturated soil.
	16,700	Dec. 22, 1933	990	.059	.72	.42	.14	.10	.79	Do.
	16,700	Jan. 2–3, 1934	665	.039	.24	.24	.18	.15	.55	Do.
	16,700	Jan. 22–23, 1934	720	.043	.24	.20	.16	.14	.95	Do.

[1] Maximum runoff for watershed.
[2] No high water for this watershed.
[3] Snow.
[4] Intense summer rain over part of watershed.

The maximum rates of runoff for the period of record on watershed of 2.33, 15.2, and 68.2 acres were 1.1, 6.0, and 17.0 second-feet, respectively. High rates of runoff have occurred several times during the period of record and higher rates are known to have occurred in the past.

Table 23 gives estimates of the runoff from watersheds of different size in the Palouse region, based on measurements of winter and spring runoff.

TABLE 23.—*Estimated runoff for different size agricultural watersheds in the Palouse region* [1]

Drainage area		Probable runoff which will be equaled or exceeded once in 10 years	
Acres	*Square miles*	*Second-feet*	*Second-feet-per-square-mile*
2	------	1	---
10	------	5	---
20	------	8	---
50	0.078	14	180
100	.156	22	141
200	.312	36	115
320	.5	50	100
640	1.0	85	85
1,280	2.0	141	70
3,200	5.0	292	58
6,400	10.0	510	51
12,800	20.0	870	43
19,200	30.0	1,170	39

[1] This table is based on measurements of winter and spring runoff.

DISCUSSION OF RESULTS

The erosion problem in the Palouse region is closely associated with the climatic factors, physical characteristics of the soil, and farming practices which affect the vegetal cover, soil-moisture content, surface-storage capacity, and the rate of infiltration. Each of these factors must be carefully considered in formulating an erosion-control program.

The concentration of the precipitation in the winter months when evaporation is at a low rate results in heavy runoff and soil losses during the months of December, January, February, and March. Erosion during the balance of the year is relatively light. Therefore, the major part of the erosion occurs when plants are dormant and when no tillage operations are being performed. The vegetal cover on cultivated land must be provided by crop residues because the climatic conditions are not suitable for the growth of winter cover crops and the cover provided by winter wheat during the erosion season is usually inadequate. The severe winter and early spring erosion is caused by continued precipitation falling on wet or saturated soil, melting snow with or without rain on frozen soil, or runoff flow across lower slopes and bottom land caused by the melting of snowdrifts on steep north slopes.

Rainfall characteristics have an important effect on the amount and rate of soil erosion. The results show that runoff and soil losses are more closely correlated with the intensity of the precipitation than with the total amount. Many of the storms that result in a large amount of precipitation have relatively low intensities; and unless they occur when the soil is very wet, the losses from erosion are slight. High-intensity rains usually cause runoff even though the amount of rain may be small and the soil-moisture content low.

The amount of moisture in the surface soil at the time of the storm has a greater effect on erosion than the amount or intensity of the

precipitation. As the soil-moisture content increases during the period of heavy winter precipitation, the susceptibility of the soil to erosion becomes progressively greater. Under these conditions, storms of relatively low intensity or melting snow cause severe soil and water losses. The most critical period is in the late winter or early spring when precipitation of higher intensity falls on wet and compacted soil.

Relatively large water losses may result from melting snow with or without rain, when the soil is frozen. The total runoff under these conditions is closely correlated with the amount of snow on the ground and the rainfall, regardless of the type of plant cover, because the rate of infiltration of water is very low. Consequently, the runoff from land covered with heavy wheat stubble may be greater than that from bare, fallow land because the stubble will hold a larger amount of drifting snow. Soil losses, however, are usually slight with this type of runoff, except on tilled land that has the surface thawed above a frozen layer.

Severe erosion in the Palouse region results from the formation of large snowdrifts on steep north slopes. The melting of the snow causes rill erosion on the slope and in the field waterways below the drift. Effective control practices for this type of erosion include seeding the steep north slopes and the waterways to grass, alfalfa-grass mixtures, or other perennial plants or the prevention of the formation of drifts by hilltop tree plantings or snow fences.

The maintenance of an adequate vegetal cover during the winter months is one of the most effective means of reducing runoff and soil losses. A satisfactory cover is generally provided by established stands of grass, alfalfa grass, or sweetclover-grass mixtures, or standing winter wheat stubble. Spring wheat stubble is not as effective as winter wheat stubble because the density of the stand of spring wheat is less than that of winter wheat. Land seeded to winter wheat and not protected by a crop-residue mulch is subject to very severe erosion. Summer-fallowed land is more erodible than fall-plowed cropped land because of its finer tilth and higher soil-moisture content.

The utilization of crop residues so that a portion is left on the surface as a mulch is a very effective erosion-control practice, especially on land seeded to winter wheat. The effectiveness of this practice is directly related to the amount of material on the surface after the seeding operation has been completed.

The incorporation of a large amount of wheat straw introduces problems regarding tillage and seeding operations and certain soil-fertility relationships. Most of the tillage implements in common use in this area cannot be readily operated in extra heavy stubble, nor are they well designed for the purpose of leaving sufficient stubble on the surface to control erosion. Fall-seeding operations with present equipment are also impeded when the stubble mulch is heavy enough for adequate erosion control under severe erosion conditions. Crop yield and other data show that the amount of available nitrogen is decreased by application of wheat straw to the soil. Additional investigations are needed for the development or modification of tillage implements and farming practices. This would permit the more efficient utilization of crop residues and encourage a more extensive use of an effective erosion-control practice.

Significant differences in erodibility as effected by the soil organic-matter content indicate that the maintenance of organic matter is one of the basic features of an effective erosion-control program. It is recognized that organic matter, especially if it is active, serves as an aggregating agent in soils. The stable aggregates produce an increase in the rate of infiltration of water into the soil and thereby reduce the amount of runoff.

An erosion-control program should include certain basic measures but the application of these may be affected by climatic characteristics, soils, and other variables. In the sections of higher rainfall in the Palouse region where annual cropping is practiced, the farming system followed should provide for: Maximum practical protection during each winter season by means of plant covers or rough, loose fall tillage; the growing of legume-grass mixtures, such as sweet-clover grass and alfalfa-grass; and the utilization of crop residues.

Sweetclover can be used as a green-manure crop or for pasture. The length of the rotation should be determined by the use-capability classification of the land. Land which has not been severely eroded and is in a relatively high state of fertility does not require the sweet-clover crop as frequently as land located on steeper slopes or which has been more severely eroded. The most severely eroded and steepest sloping land should be farmed to a long-term rotation including the use of alfalfa and grass and a smaller proportion of cultivated crops. Tillage operations in the fall preceding the seeding of a spring crop are most effective for erosion control if a loose cloddy condition of the surface soil is obtained with a considerable part of the crop residues left on or near the surface.

In the drier sections of the Palouse, the common cropping system consists of winter wheat and summer fallow. The critical erosion period is the winter season following the seeding of the winter wheat. A satisfactory method of control is the utilization of crop residues so that an effective stubble mulch is present after the winter wheat has been seeded.

Results indicate that terracing is not practical on slopes steeper than about 15 percent because of the cost of construction and maintenance and the difficulties experienced in the operation of large farm machinery. The use of terracing has not been generally recommended in this area because of the large-scale farming operations, irregular topography, and excessively steep slopes. The terracing program has been adopted to a limited extent in the Blue Mountain foothill section of southeastern Washington where the slopes are longer and not so steep.

A modified system of strip cropping may be applied to the Palouse region by dividing the fields into two or more parts on the basis of topography and land use capability. The eroded hilltops and adjacent steep north slopes should be cropped to grass, alfalfa, or trees, or to long-term rotations in which grass and alfalfa are the dominant crops. This practice furnished effective erosion control on such land and reduces the runoff across the other parts of the field.

The regular cultivated crops should be grown in rotation on the more gently sloping and less eroded land. This land may be farmed as one unit unless there is a wide variation in the fertility and erodibility between the upper and lower parts of the slopes. The more erodible soil on the upper slopes requires the use of sweet clover and

the adoption of other control practices, such as crop-residue utilization and rough tillage, to a greater extent than the less erodible soil on the lower slopes.

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APPENDIX

In order to avoid an excess of tabular material throughout the text, the data of the individual tables necessary for deriving the summary tables and figures used in the text have been placed in this appenix as tables 24 to 33.

The data presented in this appendix probably will be of only minor interest to the casual reader, but, as they give specific records of the results of experimentation from year to year, they will be of practical value and interest to technical workers in the field of soil conservation. Observational data briefly describing important seasonal and daily conditions are also appended.

TABLE 24.—*Precipitation at 5 locations in the problem area tabulated as 3-year moving averages for the period 1893–1941*

Date	Pullman, Wash.	Average of 5 [1] locations	Date	Pullman, Wash.	Average of 5 [1] locations
	Inches	*Inches*		*Inches*	*Inches*
1893–95	20.04	20.56	1917–19	18.53	17.34
1894–96	21.14	20.37	1918–20	18.12	17.54
1895–97	23.52	21.32	1919–21	20.03	19.46
1896–98	23.76	21.97	1920–22	19.06	17.63
1897–99	24.43	22.93	1921–23	18.18	17.67
1898–1900	25.16	22.61	1922–24	15.75	15.71
1899–1901	24.61	23.19	1923–25	15.74	16.49
1900–1902	22.86	22.43	1924–26	18.32	17.26
1901–3	19.96	20.65	1925–27	23.84	21.38
1902–4	21.70	20.47	1926–28	24.53	21.19
1903–5	21.03	19.03	1927–29	21.29	18.32
1904–6	22.34	20.27	1928–30	17.29	14.73
1905–7	22.15	20.77	1929–31	18.38	16.01
1906–8	21.30	19.53	1930–32	20.42	18.57
1907–9	21.65	19.47	1931–33	23.00	21.25
1908–10	20.90	19.06	1932–34	22.77	20.94
1909–11	20.73	18.56	1933–35	20.11	18.54
1910–12	19.31	18.48	1934–36	16.11	15.21
1911–13	20.65	19.58	1935–37	17.73	16.97
1912–14	20.54	20.41	1936–38	17.79	17.43
1913–15	19.58	19.23	1937–39	18.01	17.34
1914–16	19.84	19.25	1938–40	17.56	18.13
1915–17	21.55	20.04	1939–41	20.41	20.74
1916–18	20.78	18.63			

[1] Pullman, Colfax, Rosalia, and Walla Walla, Wash.; and Moscow, Idaho. Annual averages for 49-year period: Pullman, 20.54 inches; Colfax, 20.12 inches; Rosalia, 18.31 inches; Walla Walla, 16.24 inches; Moscow, 21.89 inches.

TABLE 25.—*Precipitation by months for the period Jan. 1, 1931, to Dec. 31, 1941. Gage in field 3*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1931	2.27	1.28	3.38	1.07	0.60	1.24	0.05	0	0.81	1.90	2.34	3.30	18.24
1932	3.50	2.84	4.53	1.31	2.07	.28	.78	.15	.15	2.24	4.35	2.43	24.63
1933	4.43	2.76	1.84	.56	.85	1.01	.22	.48	1.55	4.42	1.66	8.23	28.01
1934	2.66	.47	2.65	.79	1.17	2.67	.20	.03	.54	2.76	2.31	3.42	19.67
1935	2.93	1.08	2.23	2.13	.25	.62	.25	.60	.26	.74	.97	2.52	14.58
1936	5.14	1.50	1.65	.62	1.08	.71	.09	.00	1.33	.27	.12	1.98	14.46
1937	3.73	3.39	2.03	3.14	.57	3.76	.90	.49	.26	1.21	3.34	4.32	27.14
1938	1.73	2.19	2.28	1.03	.89	1.06	.28	.06	.87	1.84	2.37	1.49	16.09
1939	1.33	3.98	2.91	.26	.72	.24	.57	.00	.24	.97	.36	4.04	15.62
1940	1.75	4.83	2.65	1.98	.37	.29	1.04	.00	2.76	3.93	3.74	2.51	25.85
1941	2.30	1.23	1.06	1.99	4.22	4.02	.27	1.09	1.84	1.00	2.73	3.46	25.21
Average	2.89	2.32	2.47	1.35	1.16	1.45	.42	.26	.96	1.94	2.21	3.43	20.86
Average, 1893–1941	2.72	2.11	2.19	1.49	1.48	1.29	.47	.55	1.18	1.58	2.76	2.72	20.54

TABLE 26.—*Runoff and soil loss by months from south control plot 13 (bare hard fallow) for the period July 1, 1931, to June 30, 1942*

Year	Runoff												Total
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1931	------	------	------	------	------	------	------	------	------	------	0.267	0.473	0.740
1932	1.620	1.549	1.824	0.042	0.087	------	------	------	------	0.091	1.696	1.490	8.399
1933	2.127	.952	.840	------	------	0.004	------	------	0.006	.654	.701	4.007	9.291
1934	1.179	------	.254	.031	.025	.219	------	------	------	.437	.164	.554	2.863
1935	.956	.023	.061	.099	------	------	------	------	------	------	------	.073	1.212
1936	1.313	1.117	.132	.004	.010	------	------	------	------	------	------	.222	2.798
1937	------	.802	.435	1.123	------	.883	0.079	0.062	------	.011	.698	.641	4.734
1938	.487	.604	1.020	------	------	------	------	------	------	.150	.411	.173	2.845
1939	.159	1.354	2.045	.003	------	------	------	------	------	------	------	.367	3.928
1940	.796	2.461	.760	.325	------	------	------	------	.360	1.351	.728	.044	6.825
1941	.301	.063	.069	.222	.051	.189	------	.165	.170	.080	.921	.996	3.227
1942	.150	.473	.141	------	------	------	------	------	------	------	------	------	.764
Average runoff	.826	.854	.689	.168	.016	.118	.007	.021	.049	.252	.508	.822	4.330
Runoff [1]	30.15	37.96	31.61	12.54	1.31	8.25	1.79	8.40	5.21	13.19	23.96	24.91	21.57
	Soil loss per acre												
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1931	------	------	------	------	------	------	------	------	------	------	2.128	0.836	2.964
1932	18.711	0.298	22.754	0.212	1.278	------	------	------	------	0.886	8.235	.621	52.995
1933	3.560	.065	6.599	------	------	0.038	------	------	0.038	4.557	3.789	19.544	38.190
1934	8.456	------	1.295	.031	.328	.654	------	------	------	1.758	.153	6.492	19.167
1935	.346	.010	.002	.509	------	------	------	------	------	------	------	.070	.937
1936	6.920	.279	1.712	.002	.164	------	------	------	------	------	------	1.264	10.341
1937	------	.144	5.994	11.947	------	6.169	2.136	1.043	------	.043	1.804	2.926	32.206
1938	5.326	2.502	6.939	------	------	------	------	------	------	1.303	2.288	2.780	21.138
1939	1.907	.536	3.063	.001	------	------	------	------	------	------	------	3.159	8.666
1940	.401	35.319	4.437	2.004	------	------	------	------	3.591	2.185	1.985	.067	50.039
1941	.755	.504	.476	1.092	.081	2.470	------	5.176	1.465	.350	3.138	9.466	24.973
1942	.368	4.265	.720	------	------	------	------	------	------	------	------	------	5.353
Average	4.25	3.99	4.91	1.44	.17	.85	.19	.57	.46	1.01	2.14	4.29	24.27

[1] Runoff in percentage of the precipitation. Precipitation (inches): January, 2.74; February, 2.25; March, 2.18; April, 1.34; May, 1.22; June, 1.43; July, 0.39; August, 0.25; September, 0.94; October, 1.91; November, 2.12; December, 3.30; 11-year annual average, 20.07.

TABLE 27.—*Summary of storms which caused soil losses in excess of 0.50 ton per acre from south control plot 13 (bare hard fallow) during the period July 1, 1931, to June 30, 1942*

Date	Storm characteristics				Runoff in percentage of total rain	Soil loss per storm per acre	Soil condition when storm began
	Amount	Maximum rate per hour for —					
		5-minute period	15-minute period	30-minute period			
1932	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*	*Tons*	
Mar. 24	0.46	0.24	0.18	0.18	67.6	9.23	Very wet.
Mar. 27–28	.81	.48	.24	.24	52.0	7.11	Do.
May 21	.70	1.08	.36	.20	12.4	1.28	Dry.
Nov. 16	.82	.12	.12	.12	88.9	7.57	Very wet.
1933							
Oct. 21	.70	.24	.16	.14	26.1	1.00	Moist.
Oct. 28	1.21	.36	.32	.32	25.0	2.28	Do.
Nov. 2–3	1.00	.36	.24	.18	59.3	3.40	Very wet.
Dec. 5–6	2.20	.48	.28	.20	46.7	9.19	Moist.
Dec. 8–10	2.00	.24	.20	.20	66.3	3.16	Very wet.
Dec. 14	.09	.12	.12	.06	41.1	.61	Do.
Dec. 21–23	.97	.54	.32	.16	83.9	4.97	Do.

TABLE 27.—*Summary of storms which caused soil losses in excess of 0.50 ton per acre from south control plot 13 (bare hard fallow) during the period July 1, 1931, to June 30, 1942*—Continued.

Date	Storm characteristics: Amount	Maximum rate per hour for — 5-minute period	15-minute period	30-minute period	Runoff in percentage of total rain	Soil loss per storm per acre	Soil condition when storm began
	Inches	*Inches*	*Inches*	*Inches*	*Percent*	*Tons*	
1934							
Jan. 2–3	0.58	0.24	0.20	0.16	40.0	1.43	Moist.
Jan. 16–17	.39	.24	.16	.10	30.0	1.32	Do.
Jan. 22–23	.96	.15	.15	.15	76.6	5.28	Very wet.
June 26	1.66	.36	.32	.32	12.3	.57	Dry.
Oct. 23–24	1.22	.24	.24	.22	35.8	1.76	Moist.
Dec. 21	.64	.48	.24	.16	68.8	6.46	Very wet.
1936							
Jan. 10–11	.65	.18	.10	.10	20.5	2.17	Do.
Jan. 12–13	1.08	.24	.12	.12	48.8	3.19	Do.
Mar. 27	.46	.20	.16	.16	11.7	1.13	Moist.
1937							
Mar. 2	.29	.96	.48	.26	64.6	5.13	Do.
Apr. 4	.42	.48	.32	.16	47.9	2.65	Do.
Apr. 12–13	.57	.36	.28	.24	57.4	6.05	Do.
Apr. 14–15	.43	.18	.12	.10	57.7	1.29	Very wet.
June 10	.75	.54	.36	.28	27.6	3.48	Moist.
June 18	.21	.60	.48	.30	50.0	1.18	Do.
June 22	.68	.96	.48	.30	46.9	.50	Do.
July 28	.28	1.68	.76	.48	28.2	2.14	Dry.
Aug. 13	.23	1.08	.48	.32	27.0	1.04	Do.
Nov. 13	.46	.18	.16	.12	35.7	.53	Moist.
Dec. 10–11	.69	.36	.28	.28	16.2	1.28	Do.
1938							
Jan. 22	.21	.18	.14	.08	69.0	.80	Very wet.
Feb. 1	.22	.30	.24	.18	14.5	.57	Moist.
Mar. 5	.22	.36	.16	.14	30.5	2.34	Do.
Mar. 14	.27	.18	.06	.06	30.4	1.76	Do.
Mar. 15–16	.22	.18	.08	.06	67.3	1.27	Very wet.
Oct. 10–11	.55	.84	.32	.16	15.5	1.05	Moist.
Nov. 3	.10	.84	.32	.16	65.0	.95	Very wet.
Dec. 2	.53	.30	.16	.10	7.5	1.58	Moist.
Dec. 5	.14	.21	.15	.12	40.0	1.19	Do.
1939							
Dec. 15–16	.59	.24	.20	.20	16.8	.51	Do.
Dec. 16–17	.61	.84	.60	.35	37.0	2.54	Do.
1940							
Feb. 5–6	1.24	.24	.16	.14	51.0	8.04	Very wet.
Feb. 9	.20	.12	.08	.06	54.0	1.48	Do.
Feb. 25–28	1.27	.36	.20	.18	77.9	14.74	Do.
Feb. 28	.23	.36	.20	.16	94.6	2.49	Do.
Mar. 1–2	.31	.12	.08	.06	42.6	.53	Do.
Mar. 4	.07	.18	.08	.04	87.1	.47	Do.
Mar. 7	.88	.24	.20	.20	63.1	3.47	Do.
Apr. 9	.21	.24	.24	.20	49.5	.59	Moist.
Apr. 9	.19	.48	.36	.26	63.8	1.08	Do.
Sept. 13	.49	.60	.52	.38	16.0	1.52	Dry.
Sept. 18	.71	.24	.16	.16	29.2	1.78	Moist.
Oct. 3–4	1.46	.24	.24	.18	44.3	1.38	Do.
Nov. 28–29	1.12	.24	.20	.18	31.5	1.80	Very wet.
1941							
Jan. 25	.29	.24	.24	.22	39.0	.67	Moist.
Apr. 9–10	1.17	.72	.36	.26	17.5	1.05	Dry.
June 6–8	1.13	1.44	.84	.60	40.0	2.26	Do.
Aug. 26	.50	1.92	1.08	.58	32.6	5.17	Do.
Sept. 2–3	.44	.60	.24	.22	7.3	.50	Moist.
Dec. 2–3	1.14	.36	.20	.18	27.5	6.29	Do.
Dec. 5–6	.28	.24	.16	.12	46.8	1.26	Very wet.
Dec. 16	.33	.12	.08	.06	51.2	1.03	Do.
1942							
Feb. 1	.46	.12	.08	.08	38.5	2.79	Moist.
Feb. 3	.49	.18	.12	.10	52.8	1.43	Very wet.

TABLE 28.—*Runoff and soil losses from the south control plots,*[1] *July 1, 1931, to June 30, 1942. Palouse silt loam soil, 30-percent south slope*

Plot No.	Crop condition	Crop yield per acre	Runoff		Soil loss per acre
JULY 1, 1931 TO JUNE 30, 1932—PRECIPITATION, 22.93 INCHES					
		Bushels	*Inches*	*Percent*	*Tons*
1	Winter wheat stubble		0.174	0.76	0.017
2	do		.138	.60	.042
3	do		.732	3.19	.509
		Tons			
4	Sweetclover	16.4	.791	3.45	1.111
		Bushels			
5	Winter wheat	31.3	1.740	7.59	16.603
6	Grass		1.992	8.69	5.128
7	Summer wheat stubble	28.3	.960	4.19	2.226
8	Winter wheat	31.9	3.476	15.16	36.367
		Tons			
9	Sweetclover	1.7	3.449	15.04	23.802
		Bushels			
10	Winter wheat	30.0	3.629	15.83	30.680
11	Winter wheat stubble	24.8	.799	3.48	1.565
12	Summer wheat stubble		2.625	11.45	5.209
13	Bare, untilled		5.862	25.56	46.217
14	Winter wheat stubble		4.974	21.69	10.929
15					
JULY 1, 1932, TO JUNE 30, 1933—PRECIPITATION, 21.54 INCHES					
1	Winter wheat	42.0	0.398	1.85	0.055
2	do	36.2	.114	.53	.037
3	do	44.4	2.134	9.91	1.099
4	do	50.8	1.981	9.20	1.036
5	Winter wheat stubble		2.953	13.71	1.268
6	Grass		1.309	6.08	.764
7	Summer wheat stubble	23.2	.693	3.22	.451
8	Winter wheat stubble		4.476	20.78	.487
9	Winter wheat	38.9	3.272	15.19	3.133
10	Winter wheat stubble	16.3	5.247	24.36	1.040
11	Summer wheat stubble	16.4	1.610	7.47	.719
		Tons			
12	Sweetclover	6.6	4.276	19.85	2.431
		Bushels			
13	Bare		7.200	33.43	20.004
14	Winter wheat	8.9	2.740	12.72	.386
15	do	37.9	.058	.27	.009
JULY 1, 1933, TO JUNE 30, 1934—PRECIPITATION, 27.04 INCHES					
1	Winter wheat stubble		0.003	0.01	0.011
2	do		.000	.00	.000
3	do		.083	.31	.080
4	do	15.6	.243	.90	.572
5	Winter wheat	31.7	5.073	18.76	27.792
		Tons			
6	Grass	1.5	.002	.01	.001
		Bushels			
7	Summer wheat stubble	13.3	1.225	4.53	3.960
8	Winter wheat	22.9	5.269	19.49	29.581
9	Winter wheat stubble	12.0	.774	2.86	1.600
10	Summer wheat stubble	21.5	1.480	5.47	9.235
		Tons			
11	Sweetclover	4.7	4.471	16.53	21.865
		Bushels			
12	Winter wheat	41.5	3.656	13.52	23.192
13	Bare		7.076	26.17	38.690
14	Winter wheat stubble		1.893	7.00	4.498
15	do		.298	1.10	.183

See footnote at end of table.

TABLE 28.—*Runoff and soil losses from the south control plots,*[1] *July 1, 1931, to June 30, 1942. Palouse silt loam soil, 30-percent south slope*—Continued

Plot No.	Crop condition	Crop yield per acre	Runoff		Soil loss per acre
JULY 1, 1934, TO JUNE 30, 1935—PRECIPITATION, 18.57 INCHES					
		Bushels	*Inches*	*Percent*	*Tons*
1	Winter wheat	47.5	0.192	1.03	0.423
2	do	40.8	.134	.72	1.407
3	do	51.3	.203	1.09	.102
4	Summer wheat stubble		.023	.12	.004
5	Winter wheat stubble		.050	.27	.011
		Tons			
6	Grass	.9	.025	.13	.002
		Bushels			
7	Summer wheat stubble	16.5	.015	.08	.019
8	Winter wheat stubble		.033	.18	.012
9	Summer wheat stubble	26.8	.003	.02	.000
		Tons			
10	Sweetclover	9.0	.009	.05	.000
		Bushels			
11	Winter wheat	41.9	.094	.51	.038
12	Winter wheat stubble	13.4	.007	.04	.003
13	Bare		2.294	12.35	9.271
14	Winter wheat	20.0	.725	3.90	1.048
15	do	22.9	.753	4.05	.575
JULY 1, 1935, TO JUNE 30, 1936—PRECIPITATION, 16.02 INCHES					
1	Winter wheat stubble		0.070	0.44	0.003
2	do		.017	.11	0
3	do		.023	.14	.001
		Tons			
4	Sweetclover	9.4	.260	1.62	.245
		Bushels			
5	Winter wheat	33.2	.283	1.77	1.126
		Tons			
6	Grass	.9	.208	1.30	.005
		Bushels			
7	Summer wheat stubble	32.9	.458	2.86	2.174
8	Winter wheat	37.1	.377	2.35	1.405
		Tons			
9	Sweetclover	1.5	.911	5.69	8.156
		Bushels			
10	Winter wheat	46.7	.097	.61	.001
11	Winter wheat stubble	17.6	.092	.57	.002
12	Summer wheat stubble	27.7	.109	.68	.112
13	Bare		2.649	16.54	9.148
14	Winter wheat stubble		.089	.56	.003
15	do		.091	.57	.003
JULY 1, 1936, TO JUNE 30, 1937—PRECIPITATION, 30.12 INCHES					
1	Winter wheat	48.6	0.488	2.43	0.022
2	do	38.0	.738	3.67	.075
3	do	48.0	.685	3.40	.077
4	do	45.3	.428	2.13	.114
5	Winter wheat stubble		.118	.59	.003
		Tons			
6	Grass	1.1	.178	.88	.004
		Bushels			
7	Summer wheat stubble	26.6	.021	.10	.001
8	Winter wheat stubble		.198	.98	.005
9	Winter wheat	45.7	.509	2.53	.946
10	Winter wheat stubble	18.8	.132	.66	.003
11	Summer wheat stubble	31.5	.147	.73	.012
		Tons			
12	Sweetclover	13.01	.344	1.71	.105
		Bushels			
13	Bare		3.465	17.22	25.517
14	Winter wheat	22.3	.970	4.82	2.599
15	do	14.5	3.06	1.52	.047

See footnote at end of table.

TABLE 28.—*Runoff and soil losses from the south control plots,*[1] *July 1, 1931, to June 30, 1942. Palouse silt loam soil, 30-percent south slope*—Continued

Plot No.	Crop condition	Crop yield per acre	Runoff		Soil loss per acre
			Inches	Percent	
JULY 1, 1937, TO JUNE 30, 1938—PRECIPITATION, 18.56 INCHES					
		Bushels	*Inches*	*Percent*	*Tons*
1	Winter wheat stubble		0	0	0
2	do		0	0	0
3	do		.014	.08	.001
4	do	21.7	.005	.03	.001
5	Winter wheat	35.8	.249	1.34	.114
		Tons			
6	Grass	1.4	.009	.05	0
		Bushels			
7	Summer wheat stubble	22.0	.001	.01	0
8	Winter wheat	34.9	.329	1.77	.118
9	Winter wheat stubble	15.0	.002	.01	0
10	Summer wheat stubble	7.6	.007	.04	.004
			3.60	1.94	1.063
		Tons	.131	.71	.013
11	Sweetclover	5.9			
12	Winter wheat	54.6			
13	Bare		3.601	19.40	22.721
14	Winter wheat stubble		.196	1.06	.241
15	do		.007	.04	0
JULY 1, 1938, TO JUNE 30, 1939—PRECIPITATION, 15.38 INCHES					
1	Winter wheat	42.5	0.012	0.08	0.001
2	do	29.1	.054	.35	.006
3	do	39.5	.645	4.19	.803
4	Summer wheat stubble		.128	.83	.002
5	Winter wheat stubble		.057	.37	.001
		Tons			
6	Grass	.8	.149	.97	.002
		Bushels			
7	Summer wheat stubble	32.3	.046	.30	.001
8	Winter wheat stubble		.210	1.37	.003
9	Summer wheat stubble	23.1	.074	.48	.001
		Tons			
10	Sweetclover	13.9	.077	.50	.002
		Bushels			
11	Winter wheat	42.0	.268	1.74	.010
12	Winter wheat stubble	20.2	.060	.39	.001
13	Bare		4.295	27.93	11.877
14	Winter wheat	18.4	.845	5.49	5.152
15	do	13.3	.089	.58	.002
JULY 1, 1939 TO JUNE 30, 1940—PRECIPITATION, 16.35 INCHES					
1	Winter wheat stubble		0.007	0.04	0.002
2	do		.002	.01	0
3	do		.013	.08	.004
		Tons			
4	Sweetclover	18.8	.004	.02	0
		Bushels			
5	Winter wheat	27.0	.977	5.98	6.201
		Tons			
6	Grass	.8	.021	.13	.001
		Bushels			
7	Summer wheat stubble	11.9	0	0	0
8	Winter wheat	19.5	.868	5.31	6.909
		Tons			
9	Sweetclover	9.8	.708	4.33	4.865
		Bushels			
10	Winter wheat	52.7	.504	3.08	3.574
11	Winter wheat stubble	11.9	.017	.10	0
12	Summer wheat stubble	13.5	.015	.09	.001
13	Bare		4.710	28.81	45.370
14	Winter wheat stubble		.113	.69	.295
15	do		.002	.01	.001

See footnote at end of table.

TABLE 28.—*Runoff and soil losses from the south control plots,*[1] *July 1, 1931, to June 30, 1942. Palouse silt soam soil, 30-percent south slope*—Continued

JULY 1, 1940 TO JUNE 30, 1941—PRECIPITATION, 26.59 INCHES

Plot No.	Crop condition	Crop yield per acre	Runoff		Soil loss per acre
		Bushels	*Inches*	*Percent*	*Tons*
1	Winter wheat	53.0	0.284	1.07	1.297
2	do	37.3	.059	.22	.123
3	do	46.3	.183	.69	.396
4	do	63.2	.002	.01	.001
5	Winter wheat stubble		0	0	0
		Tons			
6	Grass	1.2	.001	0	0
		Bushels			
7	Summer wheat stubble	31.0	.222	.83	.150
8	Winter wheat stubble		.026	.10	.110
9	Winter wheat	58.2	.074	.28	.252
10	Winter wheat stubble	16.0	.169	.64	.153
11	Summer wheat stubble	27.8	0	0	0
		Tons			
12	Sweetclover	23.6	.018	.07	.004
		Bushels			
13	Bare		3.377	12.70	12.206
14	Winter wheat	23.3	.809	3.04	2.941
15	do	20.2	.001	0	0

JULY 1, 1941, TO JUNE 30, 1942—PRECIPITATION, 17.58 INCHES

Plot No.	Crop condition	Runoff (Inches)	Runoff (Percent)	Soil loss per acre (Tons)
1	Winter wheat stubble	0.058	0.33	0.002
2	do	.053	.30	.009
3	do	.019	.11	.005
4	do	0	0	0
5	Winter wheat	.112	.64	4.043
6	Grass	0	0	0
7	Summer wheat stubble	0	0	0
8	Winter wheat	.221	1.26	5.694
9	Winter wheat stubble	.039	.22	.002
10	Summer wheat stubble	.039	.22	.016
11	Sweetclover	.263	1.50	.315
12	Winter wheat	.021	.12	.257
13	Bare, untilled	3.097	17.62	24.949
14	Winter wheat stubble	.122	.69	.131
15	do	0	0	0

[1] Plot 1, half length 1/200 acre; plot 2, double length, 1/50 acre: plots 1, 2, 3, 5, 8, winter wheat-summer fallow; plot 7, spring wheat fertilized; plot 4, 4-year rotation (sweetclover, sweetclover under in June, winter wheat, spring wheat); plot 5, subsoiled; plots 9, 10, 11, 12, 4-year rotation (peas and sweetclover, clover under in June, winter wheat, spring wheat); plots 14 and 15, desurfaced, winter wheat-summer fallow.

TABLE 29.—*Runoff and soil losses from the crop rotation plots, July 1, 1938, to June 30, 1942. Palouse silt loam soil, 30-percent south slope*

JULY 1, 1938 TO JUNE 30, 1939—PRECIPITATION, 15.38 INCHES

Plot No.	Crop condition	Rotation[1] No.	Runoff		Soil loss per acre
			Inches	*Percent*	*Tons*
3	Summer wheat stubble	2	0.058	0.38	0.001
4	Rough plowing	6	.015	.10	.001
6	do	8	.066	.43	.002
7	Winter wheat stubble	7	.061	.40	0
9	Winter wheat	1	.058	.38	.028
10	Winter wheat stubble	3	.095	.62	.002
12	Summer wheat stubble	4	.045	.29	.002
14	Winter wheat	5	.169	1.10	.023
16	Summer fallow	2	.133	.86	.018
18	Summer wheat stubble	6	.023	.15	.002
19	do	8	.156	1.01	.002
21	Winter wheat stubble	5	.092	.60	.003
22	do	1	.260	1.69	.017
25	Rough plowing	4	.183	1.19	.072
28	Winter wheat	7	.357	2.32	.046
29	do	3	.507	3.30	.088

See footnotes at end of table.

TABLE 29.—*Runoff and soil losses from the crop rotation plots, July 1, 1938, to June 30, 1942. Palouse silt loam soil, 30-percent south slope*—Continued

Plot No.	Crop condition	Rotation [1] No.	Runoff		Soil loss per acre
			Inches	*Percent*	*Tons*
J LY 1, 1939 TO JUNE 30, 1940—PRECIPITATION, 16.35 INCHES					
3	Summer fallow	2	1.001	6.12	14.085
4	Summer wheat stubble	6	0	0	0
6	do	8	0	0	0
7	Winter wheat	7	.744	4.55	6.551
9	Winter wheat stubble	1	0	0	0
10	Winter wheat	3	1.443	8.83	13.953
12	Rough plowing [2]	4	1.321	8.08	19.540
14	Winter wheat stubble	5	.006	.04	.003
16	Summer wheat stubble	2	0	0	0
18	Rough plowing [2]	6	.941	5.76	10.511
19	do	8	.613	3.75	6.524
21	Winter wheat	5	1.469	8.98	15.612
22	do	1	1.836	11.23	19.155
25	Summer wheat stubble	4	.104	.64	.121
28	Winter wheat stubble	7	0	0	0
29	do	3	.062	.38	.050
JULY 1, 1940, TO JUNE 30, 1941—PRECIPITATION, 26.59 INCHES					
3	Summer wheat stubble	2	0.002	0.01	0.002
4	Rough plowing	6	0	0	0
6	do	8	.001	0	0
7	Winter wheat stubble	7	0	0	0
9	Winter wheat	1	.049	.18	.064
10	Winter wheat stubble	3	.006	02	0
12	Summer wheat stubble	4	.005	.02	.001
14	Winter wheat	5	.009	.03	.009
16	Summer fallow	2	.121	.46	.208
18	Summer wheat stubble	6	0	0	0
19	do	8		0	0
21	Winter wheat stubble	5	.003	.01	.001
22	do	1	.111	.42	.024
25	Rough plowing	4	.004	.02	.001
28	Winter wheat	7	.066	.25	.079
29	do	3	.154	.58	.142
JULY 1, 1941, TO JUNE 30, 1942—PRECIPITATION, 17.58 INCHES					
3	Summer fallow	2	0.967	5.50	15.771
4	Summer wheat stubble	6	.034	.19	.014
6	do	8	.012	.07	.004
7	Winter wheat	7	.034	.19	.042
9	Winter wheat stubble	1	.010	.06	.002
10	Winter wheat	3	.103	.59	.343
12	Rough plowing [2]	4	.037	.21	.103
14	Winter wheat stubble	5	.014	.08	.004
16	Summer wheat stubble	2	.029	.16	.007
18	Rough plowing [2]	6	.242	1.38	.647
19	do	8	.245	1.39	.742
21	Winter wheat	5	.081	.46	.244
22	do	1	.614	3.49	6.961
25	Summer wheat stubble	4	.033	.19	.011
28	Winter wheat stubble	7	.007	.04	.001
29	do	3	.010	.06	.003

[1] Rotation No. 1, winter wheat-summer fallow; No. 2, spring wheat-summer fallow; No. 3, winter wheat-peas; No. 4, spring wheat-peas; No. 5, winter-wheat-peas and spring wheat under; No. 6, spring wheat-peas and spring wheat under; No. 7, winter wheat-Hubam clover under; No. 8, spring wheat-Hubam clover under.

[2] The furrows were placed at right angles to the contour when the pea land in rotation 4 and the green-manure land in rotations 6 and 8 were plowed in 1938 and 1939. It is believed that the high erosion losses on these plots in the spring of 1940 were caused, to a large degree, by this practice. Contour tillage was practiced in 1940 and 1941.

TABLE 30.—*Surface runoff and soil loss in runoff from graded terraces* [1] *with different vertical spacings, 1932–38*

Date	Average rate of rainfall for period of— 5 minutes	15 minutes	30 minutes	Total rainfall	Total runoff Terrace 3 [2]	Terrace 3A [2]	Terrace 4	Terrace 5	Soil loss per acre Terrace 3 [2]	Terrace 3A [2]	Terrace 4	Terrace 5	Crop
1932	*In. per hour*	*In. per hour*	*In. per hour*	*In.*	*In.*	*In.*	*In.*	*In.*	*Tons*	*Tons*	*Tons*	*Tons*	
Jan. 9	0.16	0.16	0.15	0.49	0	----	0	0	0	----	0	0	Winter wheat following peas. No vegetative cover.
Jan. 11	.33	.33	.30	.69	0.02	----	0.02	0.03	0.100	----	0.078	0.096	
Jan. 18	.16	.16	.16	.66	.14	----	.05	.11	.025	----	.015	.030	
Feb. 21–22	----	----	----	.09	.03	----	.01	.01	.004	----	.002	.001	
Feb. 23	----	----	----	----	.08	----	.04	.01	.011	----	.009	.001	
Feb. 24	----	----	----	.12	.10	----	.09	.07	.057	----	.053	.004	
Feb. 25	----	----	----	.08	.04	----	.06	.09	.023	----	.035	.045	
Feb. 26	----	----	----	.04	0	----	0	.01	0	----	0	.006	
Feb. 27–28	----	----	----	.21	0	----	0	0	0	----	0	0	
Mar. 5–6	----	----	----	.26	.02	----	.01	.03	.046	----	.022	.100	
Mar. 17	.18	.17	.14	.55	.01	----	.01	.04	.034	----	.022	.102	
Mar. 18	----	----	----	.41	.05	----	.04	.08	.170	----	.274	.205	
Mar. 19	----	----	----	.14	.02	----	.02	.03	.052	----	.066	.092	
Mar. 20	----	----	----	.11	.01	----	.01	.01	.025	----	.034	.030	
Mar. 21	----	----	----	.16	.01	----	.01	.02	.025	----	.042	.054	
Mar. 24	.30	.24	.21	.45	.17	----	.16	.17	.686	----	.716	.664	
Mar. 27–28	.42	.32	.24	.73	.45	----	.40	.32	3.070	----	2.455	.910	
Apr. 2	----	----	----	.16	.01	----	.02	.01	.054	----	.096	.048	
Total	----	----	----	----	1.16	----	.95	1.04	4.382	----	3.919	2.388	
Apr. 3 to Nov. 15	----	----	----	----	(3)	(3)	(3)	(3)	----	----	----	----	
Nov. 16	.13	.13	.13	.71	0	0	0	.01	0	0	0	.002	Winter wheat stubble.
Dec. 19	.12	.12	.12	[4] .64	.16	.07	.13	.16	.003	.005	.004	.004	
Dec. 20	----	----	----	----	0	0	.01	.02	0	0	.001	.001	
Dec. 23	----	----	----	----	.01	0	0	.02	0	0	0	.001	
Dec. 26	.16	.16	.15	.27	.51	.48	.62	.33	.015	.040	.011	.007	
Dec. 27	----	----	----	[4] .04	.03	0	.04	.02	.001	0	.002	.001	
Dec. 29	----	----	----	[4] .30	.05	.03	.06	.04	0	.002	.004	.001	
Total	----	----	----	----	.76	.58	.86	.60	.019	.047	.022	.017	
Total for year	----	----	----	----	----	----	1.81	1.64	----	----	3.941	2.406	
1933													
Jan. 4	----	----	----	[4] .10	0	.28	.02	0	----	.019	0	----	Ground cover of winter wheat stubble.
Jan. 5	----	----	----	.07	.05	.59	.03	.02	.002	.040	0	0	
Jan. 7	.12	.12	.12	.55	.06	.17	.03	.07	.006	.023	.002	.004	
Jan. 8	.16	.16	.08	.26	0	.14	0	.01	----	.019	----	.001	
Jan. 9	----	----	----	.08	0	.01	0	0	----	.019	----	----	
Feb. 21	----	----	----	----	0	.01	0	0	----	0	----	----	
Feb. 22	.12	.08	.07	.22	.17	.21	.57	.40	.005	.009	.015	.009	
Feb. 23	----	----	----	[4] .66	0	.01	.14	0	----	0	.004	----	
Mar. 1	----	----	----	----	.11	.20	.27	.03	.009	.205	.034	.003	
Mar. 2	.24	.20	.16	.30	.06	.06	.08	.06	.005	.118	.010	.005	
Mar. 3	----	----	----	----	.02	.03	.01	.02	.002	.059	.002	.005	
Total	----	----	----	----	.47	1.71	1.15	.61	.029	.511	.067	.027	
Mar. 4 to Oct. 28	----	----	----	----	(3)	(3)	(3)	(3)	----	----	----	----	
Oct. 29	----	----	----	0	0	0.01	0	0	----	.004	----	----	Winter wheat on summer fallow.
Nov. 2	.30	.22	.18	.91	.05	.10	0	0	.068	.039	----	----	
Nov. 3	.48	.28	.22	.50	.12	.38	.02	.06	.102	.220	.021	.042	
Dec. 6	.48	.32	.20	1.82	.46	.64	.19	.15	.931	1.087	.286	.222	
Dec. 8	----	----	----	.20	.04	0	0	0	.044	----	----	----	
Dec. 9	.21	.18	.18	1.53	.83	.87	.53	.33	.925	.951	.400	.191	
Dec. 10	.12	.08	.08	.31	.12	.18	.10	.04	.134	.197	.082	.023	
Dec. 11	.20	.12	.10	.16	.03	.07	.02	.01	.002	.080	.004	.005	
Dec. 12	----	----	----	.17	.05	.02	.03	0	.004	.009	.006	----	
Dec. 13	----	----	----	.13	.07	.05	.04	.03	.125	.042	.054	.028	
Dec. 14	.12	.08	.06	.10	.04	.05	.02	.02	.035	.021	.010	.008	
Dec. 18	.18	.10	.10	.65	.27	.38	.19	.10	.122	.142	.072	.021	
Dec. 19	.03	.03	.02	.13	.10	.16	.09	.04	.064	.064	.034	.008	
Dec. 20	----	----	----	.25	.15	.17	.09	.04	.238	.064	.034	.013	
Dec. 21	.24	.18	.16	.18	.14	.13	.10	.06	.230	.050	.122	.102	
Dec. 22	.72	.28	.14	.79	.47	.57	.40	.33	1.210	1.122	.770	.476	
Dec. 23	----	----	----	----	.05	.21	.04	.03	.299	.471	.158	.064	
Dec. 24	----	----	----	----	0	.10	0	0	----	.022	----	----	
Dec. 25–31	----	----	----	[4] .60	0	.14	0	0	----	.014	----	----	
Total	----	----	----	----	2.99	4.23	1.86	1.24	4.533	4.599	2.053	1.203	
Total for year	----	----	----	----	3.46	5.94	3.01	1.85	4.562	5.110	2.120	1.230	

See footnotes at end of table.

TABLE 30.—*Surface runoff and soil loss in runoff from graded terraces* [1] *with different vertical spacings, 1932–38*—Continued

Date	Average rate of rainfall for period of—			Total rain fall	Total runoff				Soil loss per acre				Crop
	5 minutes	15 minutes	30 minutes		Terrace 3 [2]	Terrace 3A [2]	Terrace 4	Terrace 5	Terrace 3 [2]	Terrace 3A [2]	Terrace 4	Terrace 5	
1934	*In. per hour*	*In. per hour*	*In. per hour*	*In.*	*In.*	*In.*	*In.*	*In.*	*Tons*	*Tons*	*Tons*	*Tons*	
Jan. 2	0.12	0.10	0.08	0.21	0	0.03	0.01	0	-----	0.007	0.007	-----	Winter wheat on summer fallow.
Jan. 3	.24	.20	.18	.37	0.23	.24	.12	0.11	0.470	.372	.149	0.127	
Jan. 4	-----	-----	-----	.04	.01	.08	0	0	.002	.009	-----	-----	
Jan. 5	-----	-----	-----	-----	.01	.03	.01	.01	.002	.004	.002	.002	
Jan. 11	-----	-----	-----	-----	0	.02	0	0	-----	.006	-----	-----	
Jan. 13	.24	.18	.18	.31	.02	.11	.03	.03	.002	.045	.006	.013	
Jan. 14	-----	-----	-----	-----	0	.03	0	0	-----	.010	-----	-----	
Jan. 16	.18	.12	.10	.25	.09	.13	.06	.04	.156	.020	.044	.020	
Jan. 17	.48	.20	.12	.14	.07	.11	.05	.05	.118	.018	.036	.026	
Jan. 18–21	-----	-----	-----	.19	.04	.30	0	.02	.028	.049	-----	.004	
Jan. 22	.24	.16	.14	.74	.28	.36	.15	.11	.728	.684	.318	.328	
Jan. 23	.24	.18	.16	.26	.18	.22	.13	.09	.472	.419	.276	.269	
Jan. 24–27	-----	-----	-----	.06	0	.08	0	0	-----	.013	-----	-----	
Mar. 1	.30	.28	.20	.68	.04	.03	.07	.07	.044	.031	.078	.107	
Mar. 2	-----	-----	-----	.12	.01	.01	.04	.05	.004	.004	.044	.077	
Mar. 5	.30	.20	.20	.69	.24	.18	.17	.14	.157	.104	.206	.158	
Mar. 6	-----	-----	-----	-----	.01	.03	.01	.01	.002	.004	.004	.004	
Mar. 7 to June 30	-----	-----	-----	-----	0	0	0	0	-----	-----	-----	-----	Winter wheat disked after harvest.
July 1 to Dec. 31	-----	-----	-----	-----	0	0	0	0	-----	-----	-----	-----	
Total for year	-----	-----	-----	-----	1.23	2.10	.85	.73	2.185	1.799	1.170	1.135	
Jan. 1 to Dec. 31, 1935	-----	-----	-----	-----	(3)	(3)	(3)	(3)	-----	-----	-----	-----	
1936													
Jan. 1–2	.24	.16	.14	.90	0	.022	0	.016	0	.002	0	.001	Winter wheat following summer fallow. No vegetative cover until April. Wheat stubble disked after harvest.
Jan. 3–4	.24	.24	.18	1.17	.005	.046	.008	.017	.001	.003	0	.001	
Jan. 9	.24	.16	.12	.43	.017	0	0	.013	.002	0	0	.001	
Jan. 10–12	.24	.12	.12	1.76	.219	.645	.011	.316	.122	.166	.003	.078	
Jan. 14	.06	.06	.04	.07	0	.043	0	0	0	.003	0	0	
Jan. 19	-----	-----	-----	[4] .28	0	.018	0	0	0	.001	0	0	
Feb. 24–29	.06	.06	.05	.40	.385	.436	.047	.807	.047	.047	.008	.088	
Mar. 2	-----	-----	-----	-----	.027	.004	.005	.020	.002	.003	.001	.010	
Mar. 30	-----	-----	-----	-----	.004	0	0	.010	.001	0	0	.002	
Mar. 31 to Dec 31	-----	-----	-----	-----	(3)	(3)	(3)	(3)	-----	-----	-----	-----	
Total for year	-----	-----	-----	-----	.657	1.214	.071	1.199	.175	.225	.012	.181	
1937													
Jan. 1 to Dec. 10	-----	-----	-----	-----	(3)	(3)	(3)	(3)	-----	-----	-----	-----	Disked wheat stubble until May. Summer fallowed and seeded to winter wheat in October.
Dec. 11	.24	.24	.22	.38	0	0	.002	.005	0	0	.004	.002	
Dec. 17	.24	.12	.12	.23	.616	0	.007	.015	.017	0	.002	.003	
Total for year	-----	-----	-----	-----	.616	0	.009	.020		.017	0.006	.005	
1938													
Jan. 10–15	.24	.18	.12	.67	.027	0	0	.027	.013	0	0	.023	Winter wheat following summer fallow. No vegetative cover.
Jan. 18–23	-----	-----	-----	[4] .41	.033	.025	.010	.030	.036	.012	.012	.046	
Feb. 23–26	-----	-----	-----	-----	.029	0	0	.007	.001	0	0	.000	
Feb. 26–28	-----	-----	-----	-----	.016	0	.009	.017	.000	0	.000	.001	
Feb. 28–Mar. 2	-----	-----	-----	-----	.027	0	.013	.013	.007	0	.009	.001	
Mar. 2–3	.12	.08	.06	.11	0	0	.004	.011	0	0	.007	.003	
Mar. 3–5	.24	.15	.14	.25	.011	.005	.005	.016	.005	.002	.003	.005	
Mar. 14–15	.12	.12	.08	.44	.011	.003	.007	.017	.004	.001	.003	.004	
Mar. 15–16	.12	.08	.08	.25	.017	.008	.013	.009	.007	.003	.005	.002	
Mar. 16–22	-----	-----	-----	[4] 1.04	.016	.006	.010	.020	.024	.001	.007	.005	
Mar. 22–24	-----	-----	-----	.02	.021	.015	.030	.091	.001	.001	.003	.016	
Mar. 24–26	-----	-----	-----	-----	.006	0	0	0	.000	0	0	0	
Total (Jan. to June)	-----	-----	-----	-----	.214	.062	.101	.258	.098	.020	.049	.106	

[1] See table 2 for description of terraces.
[2] In October 1932 terrace 3A was constructed to reduce vertical spacing of terrace 3 from 35 to 20 feet.
[3] No runoff for following periods: Apr. 3–Nov. 15, 1932; Mar. 4–Oct. 28, 1933; Jan. 1–Dec. 31, 1935; Mar. 31–Dec. 31, 1936; Jan. 1–Dec. 10, 1937.
[4] Snow.

TABLE 31.—*Surface runoff and soil loss in runoff from graded terraces* [1] *of different lengths, 1932–38*

Date	Average rate of rainfall for period of—			Total rainfall	Total runoff			Soil loss per acre			Crop
	5 minutes	15 minutes	30 minutes		Terrace 2	Terrace 5	Terrace 6	Terrace 2	Terrace 5	Terrace 6	
1932	*Inch per hour*	*Inch per hour*	*Inch per hour*	*Inch*	*Inch*	*Inch*	*Inch*	*Tons*	*Tons*	*Tons*	
Jan. 9	0.16	0.16	0.15	0.49	0	0	0.01	---	---	0	Winter wheat following peas. No vegetative cover.
Jan. 11	.33	.33	.30	.69	0.24	0.03	.02	0.762	0.096	0.031	
Jan. 18	.16	.16	.16	.66	.03	.11	.09	.005	.030	.025	
Feb. 21–22	---	---	---	.09	.07	.01	.01	.010	.001	0	
Feb. 23	---	---	---	---	.08	.01	.01	.011	.001	0	
Feb. 24	---	---	---	.12	.15	.07	.05	.021	.004	.001	
Feb. 25	---	---	---	.08	.08	.09	.08	.011	.045	.004	
Feb. 26	---	---	---	.04	.03	.01	.03	.004	.006	.004	
Feb. 27–28	---	---	---	.21	0	0	.05	---	---	.091	
Mar. 5–6	---	---	---	.26	.03	.03	.18	.087	.100	.038	
Mar. 17	.18	.17	.14	.55	0	.04	.01	---	.102	.019	
Mar. 18	---	---	---	.41	0	.08	.08	---	.205	.154	
Mar. 19	---	---	---	.14	0	.03	.03	---	.092	.053	
Mar. 20	---	---	---	.11	0	.01	.01	---	.030	.200	
Mar. 21	---	---	---	.16	0	.02	.02	---	.054	.102	
Mar. 24	.30	.24	.21	.45	.04	.17	.14	.116	.664	1.006	
Mar. 27–28	.42	.32	.24	.73	.23	.32	.52	.666	.910	3.873	
Apr. 2	---	---	---	.16	0	.01	.01	---	.048	.038	
Total	---	---	---	---	.98	1.04	1.35	1.693	2.388	5.639	
Apr. 3 to Nov. 12	---	---	---	---	([2])	([2])	([2])	---	---	---	
Nov. 13	---	---	---	---	0	0	.05	---	---	.033	Winter wheat stubble.
Nov. 15	.15	.15	.14	.47	0	0	.07	---	---	.013	
Nov. 16	.13	.13	.13	.71	0	.01	.15	---	.002	.040	
Dec. 19	.12	.12	.12	[3] .64	.11	.16	.21	.002	.004	.010	
Dec. 20	---	---	---	---	.07	.02	.08	.002	.001	.002	
Dec. 21	---	---	---	---	0	.02	.05	---	0	.001	
Dec. 26	.16	.16	.15	[3] .27	.18	.33	.74	.006	.007	.020	
Dec. 27	---	---	---	.04	0	.02	.05	---	.001	.001	
Dec. 29	---	---	---	[3] .30	0	.04	.06	---	.001	.001	
Total	---	---	---	---	.36	.60	1.46	.010	.016	.121	
Total for year	---	---	---	---	1.34	1.64	2.81	1.703	2.404	5.760	
1933											
Jan. 4	---	---	---	[3] .10	.03	0	.14	.001	---	.003	Ground cover of winter wheat stubble.
Jan. 5	---	---	---	.07	.22	.02	.21	.008	0	.004	
Jan. 7	.12	.12	.12	.55	.12	.07	.18	.005	.004	.006	
Jan. 8	.16	.16	.08	.26	.01	.01	.07	0	.001	.002	
Jan. 9	---	---	---	.08	0	0	.04	---	---	.001	
Feb. 21	---	---	---	---	.02	0	.03	0	---	0	
Feb. 22	.12	.08	.07	.22	.25	.40	.26	.005	.009	.005	
Feb. 23	---	---	---	[3] .66	0	0	.02	---	---	0	
Feb. 26	---	---	---	---	0	0	.01	---	---	0	
Feb. 28	---	---	---	.12	.05	0	0	.001	---	---	
Mar. 1	---	---	---	---	.06	.03	.15	.007	.003	.004	
Mar. 2	.24	.20	.16	.30	.05	.06	.29	.007	.005	.008	
Mar. 3	---	---	---	---	.03	.02	.20	.003	.005	.005	
Mar. 4	---	---	---	---	0	0	.04	---	---	.003	
Mar. 5	---	---	---	---	0	0	.03	---	---	.002	
Mar. 7	---	---	---	[3] .25	0	0	.02	---	---	.001	
Mar. 8	---	---	---	---	0	0	.03	---	---	.002	
Mar. 9–12	---	---	---	[3] .37	0	0	.05	---	---	.012	
Total	---	---	---	---	.84	.61	1.77	.037	.027	.058	
Mar. 13 to Nov. 2	---	---	---	---	([2])	([2])	([2])	---	---	---	

See footnotes at end of table.

TABLE 31.—*Surface runoff and soil loss in runoff from graded terraces* [1] *of different lengths, 1932–38*—Continued

Date	Average rate of rainfall for period of—			Total rainfall	Total runoff			Soil loss per acre			Crop
	5 minutes	15 minutes	30 minutes		Terrace 2	Terrace 5	Terrace 6	Terrace 2	Terrace 5	Terrace 6	
	Inch per hour	*Inch per hour*	*Inch per hour*	*Inch*	*Inch*	*Inch*	*Inch*	*Tons*	*Tons*	*Tons*	
1933											
Nov. 3	0.48	0.28	0.22	0.50	0.04	0.06	0.01	0.009	0.042	0.009	Winter wheat on summer fallow.
Dec. 6	.48	.32	.20	1.82	.15	.15	[4].25	.212	.222	.354	
Dec. 9	.21	.18	.18	1.53	.48	.33	[5].80	.234	.191	.866	
Dec. 10	.12	.08	.08	.31	.09	.04	.10	.043	.023	.108	
Dec. 11	.20	.12	.10	.16	.03	.01	.02	.009	.005	.010	
Dec. 12	------	------	------	.17	.02	0	0	.004	------	------	
Dec. 13	------	------	------	.13	.03	.03	.03	.024	.028	.028	
Dec. 14	.12	.08	.06	.10	.04	.02	.02	.016	.008	.006	
Dec. 18	.18	.10	.10	.65	.35	.10	.08	.038	.021	.021	
Dec. 19	.03	.03	.02	.13	.26	.04	.03	.068	.008	.008	
Dec. 20	------	------	------	.25	.21	.04	.04	.233	.013	.013	
Dec. 21	.24	.18	.16	.18	.07	.06	.10	.078	.102	.102	
Dec. 22	.72	.28	.14	.79	.55	.33	.39	.842	.476	.476	
Dec. 23	------	------	------	------	.08	.03	.03	.192	.064	.064	
Total	------	------	------	------	2.40	1.24	1.90	2.002	1.203	2.065	
Total for year	------	------	------	------	3.24	1.85	3.67	2.039	1.230	2.123	
1934											
Jan. 2	.12	.10	.08	.21	.03	0.	0	.028	------	------	Winter wheat on summer fallow.
Jan. 3	.24	.20	.18	.37	.24	.11	.13	.305	.127	.128	
Jan. 4	------	------	------	.04	.01	0	0	0	------	------	
Jan. 5	------	------	------	------	.02	.01	0	.006	.002	------	
Jan. 13	.24	.18	.18	.31	0	.03	.01	------	.013	.001	
Jan. 16	.18	.12	.10	.25	.01	.04	.01	.009	.020	.006	
Jan. 17	.48	.20	.12	.14	.06	.05	.01	.090	.026	.006	
Jan. 19	.12	.10	.06	.15	.01	.01	.01	.009	.002	.003	
Jan. 21	------	------	------	.04	.01	.01	0	.009	.002	------	
Jan. 22	.24	.16	.14	.74	.11	.11	.17	.226	.328	.310	
Jan. 23	.24	.18	.16	.26	.12	.09	.12	.244	.269	.219	
Mar. 1	.30	.28	.20	.68	.01	.07	.05	0	.107	.040	
Mar. 2	------	------	------	.12	.01	.05	.01	001	.077	.004	
Mar. 5	.30	.20	.20	.69	.02	.14	.19	.003	.158	.098	
Mar. 6	------	------	------	------	0	.01	0	------	.004	------	
Mar. 7 to June 30	------	------	------	------	0	0	0	------	------	------	Winter wheat disked after harvest.
July 1 to Dec. 31	------	------	------	------	0	0	0	------	------	------	
Total	------	------	------	------	.66	.73	.71	.930	1.135	.815	
Jan. 1 to Dec. 31, 1935	------	------	------	------	(2)	(2)	(2)	------	------	------	
1936											
Jan. 1–2	.24	.16	.14	.90	------	.016	.007	------	.001	0	Winter wheat following summer fallow. No vegetative cover until April. Wheat stubble disked after harvest.
Jan. 3–4	.24	.24	.18	1.17	.012	.017	.009	0	.001	.001	
Jan. 9	.24	.16	.12	.43	------	.013	------	------	.001	------	
Jan. 10–12	.24	.12	.12	1.76	.047	.316	------	.005	.078	------	
Jan. 13–Feb. 29.	------	------	------	[3].78	.044	.807	[4].853	.002	.088	[4].046	
Mar. 2	------	------	------	------	------	.020	------	------	.010	------	
Mar. 30	------	------	------	------	------	.010	------	------	.002	------	
Mar. 31–Dec. 31.	------	------	------	------	(2)	(2)	(2)	------	------	------	
Total	------	------	------	------	.103	1.199	.869	.007	.181	.047	
1937											
Jan. 1 to Dec. 10.	------	------	------	------	(2)	(2)	(2)	------	------	------	Disked wheat stubble until May. Summer-fallowed and seeded to winter wheat in October.
Dec. 11	.24	.24	.22	.38	------	.005	------	------	.002	------	
Dec. 17	.24	.12	.12	.23	------	.015	.002	------	.003	.001	
Total	------	------	------	------	------	.020	.002	------	.005	.001	

See footnotes at end of table.

TABLE 31.—*Surface runoff and soil loss in runoff from graded terraces* [1] *of different lengths, 1932–38*—Continued

Date	Average rate of rainfall for period of—			Total rainfall	Total runoff			Soil loss per acre			Crop
	5 minutes	15 minutes	30 minutes		Terrace 2	Terrace 5	Terrace 6	Terrace 2	Terrace 5	Terrace 6	
1938	*Inch per hour*	*Inch per hour*	*Inch per hour*	*Inch*	*Inch*	*Inch*	*Inch*	*Tons*	*Tons*	*Tons*	
Jan. 10–15	0.24	0.18	0.12	0.67	------	0.027	0.008	------	0.023	0.019	Winter wheat following summer fallow. No vegetative cover.
Jan. 18–23	------	------	------	[3] .30	------	.030	.009	------	.046	.013	
Feb. 24–25	------	------	------	------	------	------	.001	------	------	0	
Feb. 25–26	------	------	------	------	------	.007	------	------	0	------	
Feb. 26–28	------	------	------	------	------	.017	------	------	0	------	
Feb. 28–Mar. 2	------	------	------	------	------	.013	.005	------	.001	.002	
Mar. 2–3	.12	.08	.06	.18	------	.011	------	------	.003	------	
Mar. 3–5	.24	.15	.14	.25	------	.016	.005	------	.005	.002	
Mar. 14–15	.12	.12	.08	.44	------	.017	.004	------	.004	.001	
Mar. 15–16	.12	.08	.08	.25	------	.009	.008	------	.003	.002	
Mar. 16–22	------	------	------	[3] 1.04	------	.020	.007	------	.005	.001	
Mar. 22–24	------	------	------	.02	------	.091	.008	------	.016	.001	
Total (Jan. to June).	------	------	------	------	------	.258	.055	------	.106	.041	

[1] See table 2 for description of terraces.
[2] No runoff for following periods: Apr. 3–Nov. 12, 1932; Mar. 13–Nov. 2, 1933; Jan. 1–Dec. 31, 1935; Mar. 31–Dec. 31, 1936; Jan. 1–Dec. 10, 1937.
[3] Snow.
[4] Squirrel hole under terrace 1,500 feet from outlet was plugged at 9:30 a. m.
[5] Squirrel hole under terrace 300 feet from outlet was plugged at 10:30 a. m.

TABLE 32.—*Surface runoff and soil loss in runoff from terraces* [1] *with different grades, 1932–38*

Date	Average rate of rainfall for period of—			Total rainfall	Total runoff					Soil loss per acre					Crop
	5 minutes	15 minutes	30 minutes		Terrace 13 [2]	Terrace 18	Terrace 17	Terrace 16	Terrace 15 [2]	Terrace 13 [2]	Terrace 18	Terrace 17	Terrace 16	Terrace 15 [2]	
1932	*Inch per hour*	*Inch per hour*	*Inch per hour*	*Inch*	*Inch*	*Inch*	*Inch*	*Inch*	*Inch*	*Ton*	*Tons*	*Tons*	*Tons*	*Ton*	
Jan. 9	0.16	0.16	0.15	0.49				0.02					0.001		Winter wheat following peas. No vegetative cover.
Jan. 11	.33	.33	.30	.69		0.02	0.02	.21			0.045	0.030	1.032		
Jan. 18	.16	.16	.16	.66		0	.02	.12				.001	.040		
Feb. 21–22				.09		0	0	.08					.008		
Feb. 23–24				.12		0	0	.14					.014		
Feb. 25				.08		.01	.01	.11			.002	.001	.010		
Feb. 26				.04		0	0	.06					.006		
Feb. 27						0	.06	.07				.032	.072		
Mar. 5						.01	.02	.11			.003	.004	.042		
Mar. 6						0	0	.06					.064		
Mar. 17	.18	.17	.14	.55		.02	.06	.09			.030	.104	.132		
Mar. 18				.41		.06	.17	.21			.195	.983	1.870		
Mar. 19				.14		.02	.03	.03			.010	.110	.211		
Mar. 20				.11		.02	.03	.02			.010	.110	.140		
Mar. 21				.16		.01	.03	.05			.056	.103	.210		
Mar. 24	.30	.24	.21	.45		.18	.14	.20			.568	1.086	1.768		
Mar. 27–28	.42	.32	.24	.73		.35	.48	.55			1.166	2.650	3.554		
Apr. 2				.16		.01	.02	.02			.045	.101	.092		
Total						.71	1.09	2.15			2.130	5.315	9.266		
Apr. 3 to Nov. 15					(3)	(3)	(3)	(3)	(3)						
Nov. 16	.13	.13	.13	.71	0	.08	.02	.04	.07		.014	.010	.013	.021	Winter wheat stubble.
Dec. 19	.12	.12	.12	[4] .64	.01	.10	.02	.03	.05	.001	.004	.001	.001	.001	
Dec. 20				0	0	.01	.02	.03	.02		.001	.001	.001	.001	
Dec. 26	.16	.16	.15	[4] .27	.21	.24	.22	.27	.49	.002	.003	.025	.025	.034	
Dec. 27				.04	.07	.01	.03	.05	.08	.002	.001	.001	.007	.008	
Dec. 28					0	.01	.05	0	.04		.001	.001		.004	
Dec. 29				.30	.05	.02	.03	.04	.11	.002	.001	.002	.008	.015	
Total					.34	.47	.39	.46	.86	.007	.025	.018	.055	.084	
Total for year						1.18	1.48	2.61			2.155	5.333	9.321		

See footnotes at end of table.

TABLE 32.—*Surface runoff and soil loss in runoff from terraces*[1] *with different grades, 1932–38*—Continued

Date	Average rate of rainfall for period of—			Total rainfall	Total runoff					Soil loss per acre					Crop
	5 minutes	15 minutes	30 minutes		Terrace 13[2]	Terrace 18	Terrace 17	Terrace 16	Terrace 15[2]	Terrace 13[2]	Terrace 18	Terrace 17	Terrace 16	Terrace 15[2]	
1933	*Inch per hour*	*Inch per hour*	*Inch per hour*	*Inch*	*Inch*	*Inch*	*Inch*	*Inch*	*Inch*	*Ton*	*Tons*	*Tons*	*Tons*	*Tons*	
Jan. 4				[4]0.10	0.02	0.01	0.02	0.34	0.64	0	0	0.001	0.013	0.014	Ground cover of winter wheat stubble.
Jan. 5				.07	.14	.01	.02	.34	.52	0.002	0.001	.001	.013	.010	
Jan. 6					0	0	0	0	.06					.010	
Jan. 7	0.12	0.12	0.12	.55	.02	.02	.05	.22	.21	0	.001	.003	.015	.027	
Jan. 8	.16	.16	.08	.26	.01	.01	0	.18	.25	0	0		.014	.033	
Jan. 9				.08	0	0	0	.04	.08				.003	.010	
Feb. 21					0	0	0	.05	0				.006		
Feb. 22	.12	.08	.07	.22	.02	.01	.03	.17	.23	.001	0	.003	.021	.027	
Feb. 23				[4].66	.03	0	0	0	.02	.001				.003	
Feb. 27–28				.12	0	0	0	0	.12					.013	
Mar. 1					.06	.01	.02	.18	.14	.005	.002	007	.044	.017	
Mar. 2	.24	.20	.16	.30	.46	0	.01	.15	.16	.051		.003	.038	020	
Mar. 3				0	.17	0	0	.07	.09	.015			.017	.013	
Mar. 7–10				[4].59	0	0	0	.03	0				.012		
Total					.93	.07	.15	1.77	2.52	.075	.004	.018	.196	.197	
Mar. 11 to Oct. 28					(3)	(3)	(3)	(3)	(3)						
Oct. 29					.01	0	0	.02	.01	.001			.010	.004	Winter wheat on summer fallow.
Oct. 31	.36	.22	.16	.73	0	.01	.01	.07	.03		.005	.014	.036	.014	
Nov. 2	.30	.22	.18	.91	0	.05	.16	.23	.17		.044	.218	.058	.041	
Nov. 3	.48	.28	.22	.50	.14	.08	.28	.28	.40	.010	.070	.378	.444	.786	
Nov. 4–5					0	0	0	.07	0				.014		
Dec. 6	.48	.32	.20	1.82	.54	[5].68	[5].63	.73	.91	.352	1.080	2.235	2.635	3.688	
Dec. 7–8				.20	0	.04	.06	.04	.01		.024	.240	.052	.016	
Dec. 9	.21	.18	.18	1.53	[6].80	.97	.85	.74	1.00	[6].220	.608	1.550	2.505	2.795	
Dec. 10	.12	.08	.08	.31	[6].14	.11	.20	.20	.15	[6].038	.069	.366	.471	.420	
Dec. 11	.20	.12	.10	.16	[6].03	.03	.08	.08	.08	[6].003	.016	.062	.058	.079	
Dec. 12				.17	[6].04	0	.06	.10	.11	[6].004		.046	.078	.109	
Dec. 13				.13	[6].06	.03	.06	.15	.10	[6].008	.035	.142	.335	.310	
Dec. 14	.12	.08	.06	.10	[6].03	.02	.03	.11	.03	[6].003	.008	.020	.072	.047	
Dec. 15–16				[4].50	0	0	0	.04	0				.004		
Dec. 17				[4].15	[6].02	.01	0	.05	.13	[6].002	.002		.004	.042	
Dec. 18	.18	.10	.10	.65	[6].32	.25	.24	.29	.61	[6].050	.092	.150	.224	.268	
Dec. 19	.03	.03	.02	.13	[6].17	.09	.10	.17	.26	[6].026	.038	.046	.151	.121	
Dec. 20				.25	[6].35	.07	.05	.20	.16	[6].138	.090	.022	.181	.073	
Dec. 21	.24	.18	.16	.18	[6].12	.14	.03	.20	.24	[6].048	.129	.012	.181	.111	
Dec. 22	.72	.28	.14	.79	[6].52	.57	.84	.64	.81	[6].252	1.225	2.990	2.990	3.430	

Dec. 23				0	[6].09	.05	.10	.16	.17	[6].052	.009	.535	.699	1.075	
Dec. 24				0	0	0	0	.12	.10				.009	.006	
Dec. 25				0	0	0	0	.05	.02				.004	.001	
Dec. 26–27				[4].46	0	0	0	.01	.04				0	.002	
Dec. 28				.07	.01	.03	0	.05	.07	.001	.002		.004	.005	
Dec. 29				0	.04	.03	0	.08	.10	.002	.002		.004	.008	
Dec. 30				.07	0	.01	0	.02	.10		0		.001	.008	
Dec. 31				0	0	0	0	0	.10					.008	
Total					3.43	3.27	3.78	4.90	5.91	1.210	3.648	9.026	11.224	13.467	
Total for year					4.36	3.34	3.93	6.67	8.43	1.285	3.652	9.044	11.420	13.664	
1934															
Jan. 1					0	0	.02	.02	.02			.002	.012	.011	
Jan. 2	.12	.10	.08	.21	.02	.02	.05	.06	.13	.004	.009	.038	.039	.100	
Jan. 3	.24	.20	.18	.37	.16	.17	.22	.23	.24	.032	.190	.394	.500	.845	
Jan. 4					0	.01	.01	.03	.02		.002	.006	.005	.003	
Jan. 5					.01	0	.01	.02	.01	.002		.006	.002	.002	
Jan. 13	.24	.18	.18	.31	0	.01	.02	.02	.08		.006	.018	.082	.131	
Jan. 14					0	0	0	0	.02					.009	
Jan. 15					0	0	0	0	.02					.009	
Jan. 16	.18	.12	.10	.25	.02	.05	.07	.03	.09	.005	.030	.039	.014	.042	Winter wheat on summer fallow.
Jan. 17	.48	.20	.12	.14	.05	.02	.03	.05	.11	.011	.012	.018	.023	.051	
Jan. 18–21				.19	.02	.05	.13	.11	.21	.004	.018	.082	.048	.092	
Jan. 22	.24	.16	.14	.74	.28	.34	.37	.28	.37	.117	.448	1.210	1.526	2.052	
Jan. 23	.24	.18	.16	.26	.19	.19	.22	.13	.20	.084	.252	.720	.709	1.110	
Jan. 24–27				.06	0	0	0	.05	.07				.010	.007	
Mar. 1	.30	.28	.20	.68	.06	.18	.11	.09	.07	.019	.144	.259	.278	.113	
Mar. 2				.12	.08	.05	.02	.06	.07	.031	.024	.012	.186	.113	
Mar. 4				.06	0	.04	0	.02	.04		.012		.004	.028	
Mar. 5	.30	.20	.20	.69	.23	.31	[7].22	[7].15	.25	.036	.188	.378	.388	.562	
Mar. 6					.01	.02	.02	.02	.03	.002	.006	.011	.004	.022	
Mar. 7 to June 30					0	0	0	0	0						Winter wheat disked after harvest.
July 1 to Dec. 31					0	0	0	0	0						
Total					1.13	1.46	1.52	1.37	2.05	.347	1.341	3.193	3.829	5.303	
Jan. 1 to Dec. 31, 1935					(3)	(3)	(3)	(3)	(3)						

See footnotes at end of table.

TABLE 32.—*Surface runoff and soil loss in runoff from terraces* [1] *with different grades, 1932–38*—Continued

Date	Average rate of rainfall for period of— 5 minutes	15 minutes	30 minutes	Total rainfall	Total runoff: Terrace 13 [2]	Terrace 18	Terrace 17	Terrace 16	Terrace 15 [2]	Soil loss per acre: Terrace 13 [2]	Terrace 18	Terrace 17	Terrace 16	Terrace 15 [2]	Crop
	Inch per hour	*Inch per hour*	*Inch per hour*	*Inch*	*Inch*	*Inch*	*Inch*	*Inch*	*Inch*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	
1936															
Jan. 1–2	0.24	0.16	0.14	0.90	0	0	0	0.267	0.316	0	0	0	0.045	0.068	Winter wheat following summer fallow. No vegetative cover until April. Wheat stubble disked after harvest.
Jan. 3–4	.24	.24	.18	1.17	0.021	0.021	0.014	.599	.300	0.001	0.003	0.001	.214	.388	
Jan. 9	.24	.16	.12	.43	0	0	0	.048	.145	0	0	0	.003	.011	
Jan. 10–12	.24	.12	.12	1.76	.367	.210	.114	.661	.557	.069	.069	.065	.364	.397	
Jan. 14	.06	.06	.04	.07	0	0	0	.120	.201	0	0	0	.011	.018	
Jan. 23					0	0	0	.043	.035	0	0	0	.005	.004	
Jan. 27				[4] .16	0	0	0	.021	.011	0	0	0	.001	.000	
Feb. 24–29	.06	.06	.04	.37	.738	.491	.443	.849	.029	.079	.046	.063	.111	.002	
Mar. 2					0	0	.028	.074	1.069	0	0	.109	.015	.236	
Mar. 8	.24	.12	.08	.34	0	0	0	0	.007	0	0	0	0	.000	
Mar. 30					0	.007	0	0	0	0	.002	0	0	0	
Mar. 31 to Dec. 31					(3)	(3)	(3)	(3)	(3)						
Total					1.126	.729	.599	2.682	2.670	.149	.120	.238	.769	1.124	
1937															
Jan. to Dec. 10					(3)	(3)	(3)	(3)	(3)						Disked wheat stubble until May. Summer fallowed and seeded to winter wheat in October.
Dec. 11	.24	.24	.22	.38	0	.003	.024	.031	.028	0	.002	.010	.126	.058	
Dec. 17	.24	.12	.12	.23	0	.008	.075	.261	.028	0	.004	.078	.235	.062	
Dec. 26–30				[3] 2.32	.145	0	.366	2.088	.673	.042	0	.062	2.801	1.441	
Total					.145	.011	.465	2.380	.729	.042	.006	.150	3.162	1.561	
1938															
Jan. 10–15	.24	.18	.12	.67	0	0	.027	.093	.139	0	0	.127	.337	.149	
Jan. 15–17				[4] .41	0	0	.014	.075	.028	0	0	.007	.014	.010	
Jan. 18–23				[4] .30	0	.017	.072	.302	.477	0	.013	.216	.453	.394	
Feb. 3	.12	.06	.04	.04	0	0	0	.024	.022	0	0	0	.000	.004	
Feb. 4				[4] .06	0	0	0		.025	0	0	0	0	.004	
Feb. 6				[4] .54	0	0	0		.005	0	0	0	0	.001	
Feb. 8–10				[4] .08	0	0	.008		.010	0	0	.002	0	.000	
Feb. 10–11				.02	0	0	.013	.031	.014	0	0	.002	.007	.001	
Feb. 11–14				[4] 1.04	0	0	.014	.031	.137	0	0	.003	.008	.004	
Feb. 14–15					0	0	.018	.019		0	0	.002	.001	0	
Feb. 15–16					0	0	.008	.005		0	0	.001	.004	0	
Feb. 21–23					0	.012	.027	.027	.028	0	.001	.002	.006	.004	
Feb. 23–24					0	0	.027	.029	.028	0	0	.003	.002	.003	
Feb. 24–25					0	.011	.027	.025	.025	0	.001	.002	.002	.003	

Feb. 25–26					0	0	.025	.024	.025	0	0	.006	.006	.058	Winter wheat following summer fallow. No vegetative cover.
Feb. 26–28					.016	.013	.023	.025	.025	.001	.001	.003	.001	.031	
Feb. 28–Mar. 2					0	.002	.007	.019	.025	0	.000	.003	.004	.005	
Mar. 2–3	.12	.08	.06	.18	.016	.006	.014	.019	.015	.001	.002	.030	.008	.026	
Mar. 3–5	.24	.15	.14	.25	.005	.010	.024	.025	.018	.001	.003	.045	.037	.021	
Mar. 14–15	.12	.12	.08	.44	0	.014	.027	.029	.018	0	.009	.055	.100	.016	
Mar. 15–16	.12	.08	.08	.25	.016	.018	.027	.029	.027	.006	.007	.116	.059	.055	
Mar. 16–22				[4] 1.04	.260	.010	.236	.984	.697	.008	.006	.102	.791	.653	
Mar. 22–24				.02	.014	.017	.027	.299	.281	.001	.005	.037	.491	.337	
Mar. 24–26					0	0	.020	.022	.060	0	0	.006	.007	.020	
Total (Jan.–June)					.327	.130	.685	2.134	2.129	.018	.048	.770	2.338	1.799	

[1] See table 2 for description of terraces.
[2] This terrace not installed until after Apr. 2, 1932.
[3] No runoff for following periods: Apr. 3–Nov. 5, 1932; Mar. 11–Oct. 28, 1933; Jan. 1–Dec. 31, 1935; Mar. 31–Dec. 31, 1936; Jan.–Dec. 10, 1937.
[4] Snow.
[5] Squirrel hole 500 feet from outlet of terrace 17 was plugged at 9:30 a. m., and results are adjusted accordingly.
[6] Runoff and soil loss are for combined areas of terraces 12 and 13.
[7] Adjusted result based on incomplete record.

TABLE 33.—*Surface runoff and soil loss from graded terraces*[1] *on different land slopes, 1932–38*

Date	Average rate of rainfall for period of—			Total rainfall	Total runoff				Soil loss per acre				Crop
	5 minutes	15 minutes	30 minutes		Terrace 7	Terrace 5	Terrace 17	Terrace 3A[2]	Terrace 7	Terrace 5	Terrace 17	Terrace 3A[2]	
1932	*In. per hour*	*In. per hour*	*In. per hour*	*In.*	*In.*	*In.*	*In.*	*In.*	*Tons*	*Tons*	*Tons*	*Tons*	
Jan. 11	0.33	0.33	0.30	0.69	0.06	0.03	0.02	----	0.158	0.096	0.030	----	Winter wheat following peas. No vegetative cover.
Jan. 10	.16	.16	.16	.66	.15	.11	.02	----	.032	.030	.001	----	
Feb. 21–22	----	----	----	.09	0	.01	0	----	----	.001	----	----	
Feb. 23	----	----	----	----	0	.01	0	----	----	.001	----	----	
Feb. 24	----	----	----	.12	.23	.07	0	----	.004	.004	----	----	
Feb. 25	----	----	----	.08	.57	.09	.01	----	.040	.045	.001	----	
Feb. 26	----	----	----	.04	.54	.01	0	----	.138	.006	----	----	
Feb. 27	----	----	----	----	.12	0	.06	----	.040	----	.032	----	
Mar. 5	----	----	----	----	.29	.03	.02	----	.100	.100	.004	----	
Mar. 6	----	----	----	----	----	0	0	----	.024	----	----	----	
Mar. 17	.18	.17	.14	.55	0	.04	.06	----	----	.102	.104	----	
Mar. 18	----	----	----	.41	0	.08	.17	----	----	.205	.983	----	
Mar. 19	----	----	----	.14	0	.03	.03	----	----	.092	.110	----	
Mar. 20	----	----	----	.11	0	.01	.03	----	----	.030	.110	----	
Mar. 21	----	----	----	.16	0	.02	.03	----	----	.054	.103	----	
Mar. 24	.30	.24	.21	.45	.01	.17	.14	----	.024	.664	1.086	----	
Mar. 27–28	.42	.32	.24	.73	.09	.32	.48	----	.184	.910	2.650	----	
Apr. 2	----	----	----	.16	0	.01	.02	----	----	.048	.101	----	
Total	----	----	----	----	2.06	1.04	1.09	----	.744	2.388	5.315	----	
Apr. 3 to Nov. 15.	----	----	----	----		(3)	(3)	(3)	(3)	----	----	----	
Nov. 16	.13	.13	.13	.71	0	.01	.02	0	----	.002	.010	----	Winter wheat stubble.
Dec. 19	.12	.12	.12	[4].64	.29	.16	.02	.07	.007	.004	.001	0.005	
Dec. 20	----	----	----	----	.08	.02	.02	0	.002	.001	.001	----	
Dec. 21	----	----	----	----	.01	0	0	0	.001	----	----	----	
Dec. 23	----	----	----	----	.02	.02	0	0	.001	.001	----	----	
Dec. 26	.16	.16	.15	[4].27	1.31	.33	.22	.48	.039	.007	.002	.040	
Dec. 27	----	----	----	.04	.22	.02	.03	0	.005	.001	.001	----	
Dec. 28	----	----	----	----	0	0	.05	0	----	----	.002	----	
Dec. 29	----	----	----	[4].30	.17	.04	.03	.03	.002	.001	.002	.002	
Dec. 30	----	----	----	----	.07	0	0	0	.001	----	----	----	
Total	----	----	----	----	2.17	.60	.39	.58	.058	.017	.019	.047	
Total for year	----	----	----	----	4.23	1.64	1.48	----	.802	2.405	5.334	----	
1933													
Jan. 4	----	----	----	[4].10	.28	0	.02	.28	.002	----	.001	.019	Ground cover of winter wheat stubble.
Jan. 5	----	----	----	.07	.86	.02	.02	.59	.006	0	.001	.040	
Jan. 6	----	----	----	----	.18	0	0	0	.001	----	----	----	
Jan. 7	.12	.12	.12	.55	1.13	.07	.05	.17	.020	.004	.003	.023	
Jan. 8	.16	.16	.08	.26	.73	.01	0	.14	.013	.001	----	.019	
Jan. 9	----	----	----	.08	.13	0	0	.01	0	----	----	.019	
Feb. 21	----	----	----	----	0	0	0	.01	----	----	----	----	
Feb. 22	.12	.08	.07	.22	.28	.40	.03	.21	.007	.009	.003	.009	
Feb. 23	----	----	----	[4].66	.02	0	0	.01	0	----	----	0	
Mar. 1	----	----	----	----	.06	.03	.02	.20	.001	.003	.007	.205	
Mar. 2	.24	.20	.16	.30	.18	.06	.01	.06	.002	.005	.003	.118	
Mar. 3	----	----	----	----	.14	.02	0	.03	.001	.005	----	.059	
Mar. 7	----	----	----	[4].25	.01	0	0	0	0	----	----	----	
Mar. 8	----	----	----	----	.08	0	0	0	.001	----	----	----	
Mar. 9	----	----	----	[4].34	.03	0	0	0	0	----	----	----	
Mar. 10–11	----	----	----	----	.14	0	0	0	.005	----	----	----	
Total	----	----	----	----	4.25	.61	.15	1.71	.059	.027	.018	.511	

See footnotes at end of table.

TABLE 33.—*Surface runoff and soil loss from graded terraces* [1] *on different land slopes, 1932–38*—Continued

Date	Average rate of rainfall for period of—			Total rainfall	Total runoff				Soil loss per acre				Crop
	5 minutes	15 minutes	30 minutes		Terrace 7	Terrace 5	Terrace 17	Terrace 3A [2]	Terrace 7	Terrace 5	Terrace 17	Terrace 3A [2]	
1933	*In. per hour*	*In. per hour*	*In. per hour*	*In.*	*In.*	*In.*	*In.*	*In.*	*Tons*	*Tons*	*Tons*	*Tons*	
Mar. 12 to Oct. 28	----	----	----	----	(3)	(3)	(3)	(3)	----	----	----	----	
Oct. 29	----	----	----	----	0	0	0	0.01	----	----	----	0.004	Winter wheat on summer fallow.
Oct. 31	0.36	0.22	0.16	0.73	0	0	0.01	0	----	----	0.014	----	
Nov. 2	.30	.22	.18	.91	0	0	.16	.10	----	----	.218	.039	
Nov. 3	.48	.28	.22	.50	0	.06	.28	.38	----	0.042	.378	.220	
Dec. 6	.48	.32	.20	1.82	0	.15	[5] .63	.64	----	.222	2.235	1.087	
Dec. 7	----	----	----	----	0	0	.06	0	----	----	.240	----	
Dec. 9	.21	.18	.18	1.53	[6] .34	.33	.85	.87	0.160	.191	1.550	.951	
Dec. 10	.12	.08	.08	.31	.02	04	.20	.18	.009	.023	.366	.197	
Dec. 11	.20	.12	.10	.16	0	.01	.08	.07	----	.005	.062	.080	
Dec. 12	----	----	----	.17	0	0	.06	.02	----	----	.046	.009	
Dec. 13	----	----	----	.13	0	.03	.06	.05	----	.028	.142	.042	
Dec. 14	.12	.08	.06	.10	0	.02	.03	.05	----	.008	.020	.021	
Dec. 18	.18	.10	.10	.65	.04	.10	.24	.38	.003	.021	.150	.142	
Dec. 19	.03	.03	.02	.13	.02	.04	.10	.16	.001	.008	.046	.064	
Dec. 20	----	----	----	.25	.02	.04	.05	.17	.001	.013	.022	.064	
Dec. 21	.24	.18	.16	.18	.03	.06	.03	.13	.009	.102	.012	.050	
Dec. 22	.72	.28	.14	.79	.24	.33	.84	.57	.088	.476	2.990	1.122	
Dec. 23	----	----	----	----	.01	.03	.10	.21	.004	.064	.735	.471	
Dec. 24	----	----	----	----	0	0	0	.10	----	----	----	.022	
Dec. 25–31	----	----	----	[4] .60	0	0	0	.14	----	----	----	.014	
Total	----	----	----	----	.72	1.24	3.78	4.23	.275	1.203	9.026	4.599	
Total for year	----	----	----	----	4.97	1.85	3.93	5.94	.334	1.230	9.044	5.110	
1934													
Jan. 1	----	----	----	.08	0	0	.02	0	----	----	.002	----	Winter wheat on summer fallow.
Jan. 2	.12	.10	.08	.21	0	0	.05	.03	----	----	.038	.007	
Jan. 3	.24	.20	.18	.37	.08	.11	.22	.24	.033	.127	.394	.372	
Jan. 4	----	----	----	.04	0	0	.01	.08	----	----	.006	.009	
Jan. 5	----	----	----	----	0	.01	.01	.03	----	.002	.006	.004	
Jan. 11	----	----	----	----	0	0	0	.02	----	----	----	.006	
Jan. 13	.24	.18	.18	.31	0	.03	.02	.11	----	.013	.018	.045	
Jan. 14	----	----	----	----	0	0	0	.03	----	----	----	.010	
Jan. 16	.18	.12	.10	.25	0	.04	.07	.13	----	.020	.039	.020	
Jan. 17	.48	.20	.12	.14	0	.05	.03	.11	----	.026	.018	.018	
Jan. 18–21	----	----	----	.19	0	.02	.13	.30	----	.004	.082	.039	
Jan. 22	.24	.16	.14	.74	.02	.11	.37	.36	.008	.328	1.210	.684	
Jan. 23	.24	18	.16	.26	.04	.09	.22	.22	.017	.269	.720	.419	
Jan. 24–27	----	----	----	.06	0	0	0	.04	----	----	----	.003	
Mar. 1	.30	.28	.20	.68	0	.07	.11	.03	----	.107	.259	.031	
Mar. 2	----	----	----	.12	0	.05	.02	.01	----	.077	.012	.004	
Mar. 5	.30	.20	.20	.69	.04	.14	[7] .22	.18	.008	.158	.378	.104	
Mar. 6	----	----	----	----	0	.01	.02	.03	----	.004	.011	.004	
Mar. 7 to June 30.	----	----	----	----	0	0	0	0	----	----	----	----	Winter wheat disked after harvest.
July 1 to Dec 31.	----	----	----	----	0	0	0	0	----	----	----	----	
Total	----	----	----	----	.18	.73	1.52	2.10	.066	1.135	3.193	1.799	
Jan. 1 to Dec. 31, 1935	----	----	----	----	(3)	(3)	(3)	(3)	----	----	----	----	

See footnotes at end of table.

TABLE 33.—*Surface runoff and soil loss from graded terraces* [1] *on different land slopes, 1932–38*—Continued

Date	Average rate of rainfall for period of—			Total rainfall	Total runoff				Soil loss per acre				Crop
	5 minutes	15 minutes	30 minutes		Terrace 7	Terrace 5	Terrace 17	Terrace 3A [2]	Terrace 7	Terrace 5	Terrace 17	Terrace 3A [2]	
1936	*In. per hour*	*In. per hour*	*In. per hour*	*In.*	*In.*	*In.*	*In.*	*In.*	*Tons*	*Tons*	*Tons*	*Tons*	
Jan. 1–2	0. 24	0. 16	0. 14	0. 90	0. 007	0. 016	0	0. 022	0	0. 001	0	0. 002	Winter wheat following summer fallow. No vegetative cover until April. Wheat stubble disked after harvest.
Jan. 3–4	. 24	. 24	. 18	1. 17	. 009	. 017	0. 014	. 046	0. 001	. 001	0. 001	. 003	
Jan. 9	. 24	. 16	. 12	. 43	0	. 013	0	0	0	. 001	0	0	
Jan. 10–12	. 24	. 12	. 12	1. 76	0	. 316	. 114	. 645	0	. 078	. 065	. 166	
Jan. 13–Feb. 29	-----	-----	-----	[4]. 78	[5].853	. 807	. 443	. 497	[5].046	. 088	. 063	. 051	
Mar. 2	-----	-----	-----	-----	0	. 020	. 028	. 004	0	. 010	. 109	. 003	
Mar. 30	-----	-----	-----	-----	0	. 01	0	0	0	. 002	0	0	
Mar. 31 to Dec 31	-----	-----	-----	-----	(3)	(3)	(3)	(3)	-----	-----	-----	-----	
Total	-----	-----	-----	-----	. 869	1. 199	. 599	1. 214	. 047	. 181	. 238	. 225	
1937													
Jan. 1 to Dec. 10	-----	-----	-----	-----	(3)	(3)	(3)	(3)	-----	-----	-----	-----	Disked wheat stubble until May. Summer-fallowed and seeded to winter wheat in October.
Dec. 11	. 24	. 24	. 22	. 38	0	. 005	. 024	0	0	. 002	. 010	0	
Dec. 17	. 24	. 12	. 12	. 24	0	. 015	. 075	0	0	. 003	. 078	0	
Dec. 26–30	-----	-----	-----	[4] 2.32	0	0	. 366	0	0	0	. 062	0	
Total	-----	-----	-----	-----	-----	. 020	. 465	-----	-----	. 005	. 150	-----	
1938													
Jan. 10–15	. 24	. 18	. 12	. 67	0	. 027	. 027	0	0	. 023	. 127	0	Winter wheat following summer fallow. No vegetative cover.
Jan. 15–17	-----	-----	-----	[4]. 41	0	0	. 014	0	0	0	. 007	0	
Jan. 18–23	-----	-----	-----	[4]. 30	-----	. 030	. 072	. 025	0	. 046	. 216	. 013	
Feb. 8–10	-----	-----	-----	[4]. 08	0	0	. 008	0	0	0	. 002	0	
Feb. 10–11	-----	-----	-----	[4]. 02	0	0	. 013	0	0	0	. 002	0	
Feb. 11–14	-----	-----	-----	[4] 1.04	0	0	. 014	0	0	0	. 003	0	
Feb. 14–15	-----	-----	-----	-----	0	0	. 018	0	0	0	. 002	0	
Feb. 15–16	-----	-----	-----	-----	0	0	. 008	0	0	0	. 001	0	
Feb. 21–23	-----	-----	-----	-----	0	0	. 027	0	0	0	. 002	0	
Feb. 23–24	-----	-----	-----	-----	0	0	. 027	0	0	0	. 003	0	
Feb. 24–25	-----	-----	-----	-----	0	. 007	. 027	0	0	0	. 002	0	
Feb. 25–26	-----	-----	-----	-----	0	. 017	. 025	0	0	0	. 006	0	
Feb 26–28	-----	-----	-----	-----	0	0	. 023	0	0	0	. 003	0	
Feb. 28–2	-----	-----	-----	-----	0	. 013	. 007	0	0	. 001	. 003	0	
Mar. 2–3	. 12	. 08	. 06	. 18	0	. 011	. 014	0	0	. 003	. 030	0	
Mar. 3–5	. 24	. 15	. 14	. 25	0	. 016	. 024	. 005	0	. 005	. 045	. 002	
Mar. 14–15	. 12	. 12	. 08	. 44	0	. 017	. 027	. 003	0	. 004	. 055	. 001	
Mar. 15–16	. 12	. 08	. 08	. 25	0	. 009	. 027	. 008	0	. 003	. 116	. 003	
Mar. 16–22	-----	-----	-----	[4]1.04	. 005	. 020	. 236	. 006	. 004	. 005	. 102	0	
Mar 22–24	-----	-----	-----	. 02	0	. 091	. 027	. 015	0	. 016	. 037	. 001	
Mar 24–26	-----	-----	-----	-----	0	0	. 020	0	0	0	. 006	0	
Total (Jan.–June)	-----	-----	-----	-----	. 005	. 258	. 685	. 062	. 004	. 106	. 770	. 020	

[1] See table 2 for description of terraces.
[2] Terrace 3A was not constructed until October 1932.
[3] No runoff for following periods: Apr. 3–Nov. 15, 1932; Mar. 12–Oct. 28, 1933; Jan. 1–Dec. 31, 1935; Mar. 31–Dec. 31, 1936; Jan. 1–Dec. 10, 1937.
[4] Snow.
[5] From Jan. 13 through March runoff from terrace 6 ran onto terrace 7 through a squirrel hole which was not plugged completely until Mar. 1. Records adjusted accordingly.
[6] Value is high—includes some water from terrace 6 above.
[7] Estimated from partial record.

Observational Data Describing Important Seasonal and Daily Conditions

1931. The precipitation was 2.10 inches below normal. (The normal rainfall used for comparison is 20.54 inches, which is the average for Pullman, Wash., for the period 1893 to 1941).

January to March. Serious erosion during January from rain and melting snow.

October to December. The precipitation was about normal. Conditions were favorable for absorption and only a small amount of runoff occurred.

1932. The total annual rainfall was 4.08 inches above normal.

January to March. The precipitation was 3.64 inches above normal. Rapid melting of snow, rain, frozen ground, and saturated soil resulted in heavy runoff and serious erosion.

January 11. Considerable snow on ground which melted as rain fell. Ground saturated; frost out on most of south slopes. Very serious erosion and runoff.

January 18. Heavy runoff; ground frozen except ½ to 1 inch on top. Severe erosion but less than January 11.

February 26–27. Considerable snow in drifts with over half of ground bare. Saturated soil; frozen ground under snow; 1 to 4 inches of thawed surface where ground was bare but frost below.

February 28. Snow mostly gone except drifts on north slopes. Saturated soil; frost out on upper south slopes; some frost on lower slopes; ground frozen solid on north slopes.

March 5. About 6 inches snow on ground evening of the 4th. Chinook started in evening and rain after midnight; rain again the afternoon of 5th, snow mostly melted on upper south slopes, but some left on flats and north slopes. No frost in ground; saturated soil.

March 18. Rain; no snow or frozen ground.

March 24. Rain and extremely heavy wind; no snow or frozen ground.

March 27–28. Rain starting evening of 27th and continuing with varying intensities until 10:30 a. m. of 28th. No snow or frozen ground.

October to December. The precipitation was 1.95 inches above normal, most of the excess occurring in November. The runoff during November was due to rain on saturated ground, while the December runoff was mostly from melting snow with the ground frozen. The losses from runoff and erosion were comparatively slight, however.

1933. The precipitation was 7.45 inches above normal with most of the excess occurring in January, October, and December.

January to March. The precipitation was 2 inches above normal and was characterized by heavy snow and freezing temperatures during the latter part of January and most of February. Runoff and erosion were heavy in early January and again in late February and early March.

January 5. Snow about 18 inches deep on January 3 and fairly uniform. A chinook started January 4 and continued on the 5th. Ground frozen solid. Runoff was from melting snow.

January 7–8. Intermittent rain; melting snow. Snow and frost were gone on upper south slopes but still frozen on lower and north slopes; patches of snow.

February 22. Ground frozen solid; deep snow, drifted. Snow started to melt on 21st and continued as rain fell on 22d.

March 1–2. Deep snow on north slopes; bare in patches on south slopes. Frozen ground but with 1 to 5 inches of surface thawed out where snow was gone. Runoff from melting snow and rain on 2d.

March 10–12. Snow (0.34-inch precipitation) fell on the 9th with uniform distribution. Still large drifts on north slopes from earlier snow. Frost out on south slopes but still frozen on north slopes. Heavy runoff and erosion from melting snow.

September 9. Intense summer rain over part of watershed W–VII.

October to December. The precipitation was 7.23 inches above normal, 5.51 inches of the excess coming in December. The ground was not frozen except for a thin crust a few times. Not much runoff occurred during October and November but the runoff and soil losses were heavy in December. The runoff was due to rain and, to some extent, melting snow on unfrozen saturated ground in excess of the absorptive capacity of the soil.

December 5–6. Heavy rain. No frost.

December 9. Heavy rain; saturated soil.

December 18. Snow (0.65-inch precipitation) on ground which was melting as rain of 0.65 inch fell. Saturated soil; no frozen ground.

December 22. Saturated soil; heavy rain; no frost.

1934. The precipitation was 0.84 inch below normal.

January to March. The precipitation was about 1.22 inches below normal but the saturated condition of the soil following the heavy rains of December caused moderate runoff in January.

October to December. The precipitation was 1.43 inches above normal but intensities were low. About two-thirds of the December precipitation was snow, and about 1 inch of precipitation was on the ground as snow at the end of the month. There was only slight runoff and erosion during this period.

1935. The precipitation was 5.89 inches below normal with most of the deficit occurring in February, October, and November. The snow melted gradually in the spring with only moderate surface runoff and slight erosion. Amounts and intensities of rainfall were low, and conditions were favorable for absorption.

1936. The precipitation was 6.08 inches below normal with most of the deficit occurring in February, March, October, and November.

January. The precipitation was 2.42 inches above normal. Heavy runoff resulted from three storms during the first half of the month.

January 3–4. Runoff from rain of 1.21 inches on saturated soil, no snow or frozen ground.

January 10–11. Rain on saturated soil.

January 12. Rain on saturated soil.

February–March. The precipitation was 1.15 inches below normal but large water losses occurred during the last of February as the result of rain and melting snow on frozen ground.

October to December. The precipitation was 4.69 inches below normal. Amounts and intensities of rainfall were low, and conditions favorable for absorpton.

1937. The precipitation was 6.60 inches above normal with most of the excess occurring in January, February, April, June, and December.

January to March. The precipitation was 2.12 inches above normal with nearly all of that in January and February falling as snow and accompanied with abnormally low temperatures. The ground was frozen solid until about February 25. Large snowdrifts had accumulated on north slopes. No runoff occurred until February 20.

February 20–25. The large water losses were the result of rain and melting snow on frozen ground. Soil losses were comparatively small.

March 2–8. Heavy runoff and erosion caused by rain and melting snow on saturated soil.

April 4–20. Abnormally high precipitation on wet soil resulted in considerable soil and water losses.

October to December. The precipitation was 1.81 inches above normal, but occurred in small amounts of low intensities. Runoff and erosion were light under most conditions.

1938. The precipitation was 4.45 inches below normal. No storms of unusually great amounts or intensities were recorded.

January to March. The precipitation was 0.83 inch below normal, and consisted of about one-half snow. Nearly all of erosion losses during January and February were caused by melting snow with or without rain. The runoff in March was caused by several rains on wet soil.

October to December. The precipitation was 1.36 inches below normal. Conditions were favorable for the rapid absorption of water and low runoff.

1939. The precipitation was 4.92 inches below normal with most of the deficit occurring in January, April, and November.

January to March. The precipitation was 1.19 inches above normal and consisted of about three-fourths snow. The ground was frozen during most of January and February. Very little runoff occurred until February 11.

February 11–12 and 14–15. Heavy runoff caused by rain and melting snow on frozen ground. Small soil losses.

March 11–12 and 16–20. Heavy runoff caused by melting snow on frozen ground on north slopes.

October to December. The precipitation was 1.71 inches below normal. Runoff resulted from rain on moist soil.

1940. The precipitation was 5.31 inches above normal with most of the excess occurring in February, September, and October.

January to March. The precipitation was 1.20 inches above normal. There

was very little snow and most of the runoff was caused by rain on saturated soil.

February 25–28. Heavy runoff and erosion caused by a series of relatively intense rains on saturated soil.

March 7. Heavy rain on wet soil.

October to December. The precipitation was 3.12 inches above normal and consisted of about 10 percent snow.

November 28. Heavy runoff from rain on saturated soil.

December 18–20. Rain with ground frozen during first part of storm.

1941. The precipitation was 4.67 inches above normal with most of the excess occurring in May and June when higher temperatures and growing crops minimized erosion losses.

January to March. The precipitation was 2.44 inches below normal. Temperatures were unusually mild and resulted in little freezing.

January 17–19. Rain and melting snow on frozen ground.

October to December. The precipitation was 0.13 inch above normal with very little snow.

November 12–13 and December 2–3. Heavy runoff from rain on unfrozen ground.